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The works of the Lord are great, sought out of all them that have pleasure therein.—Ps. cxi. 2.

# THE SIDEREAL MESSENGER.

## AUGUST, 1891.

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NORTHFIELD, MINN.

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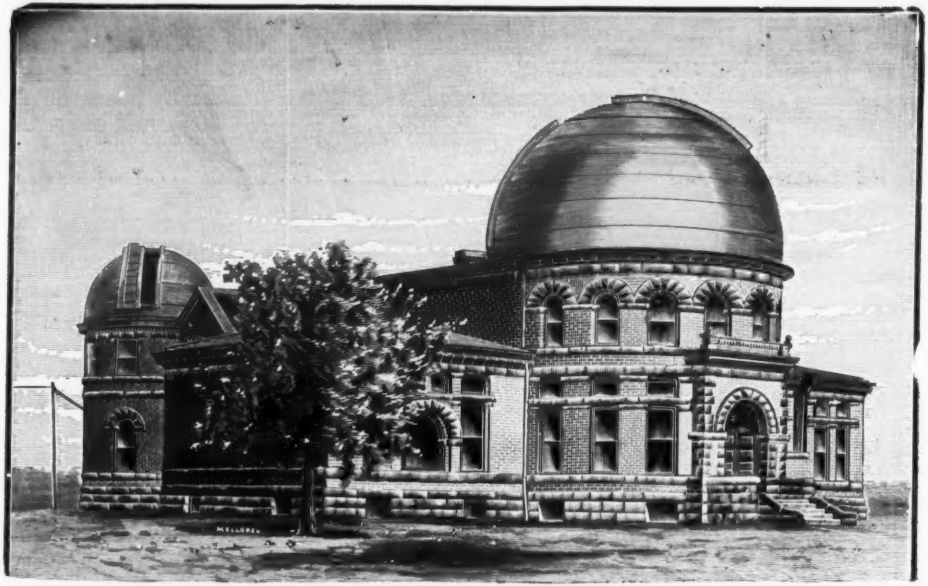

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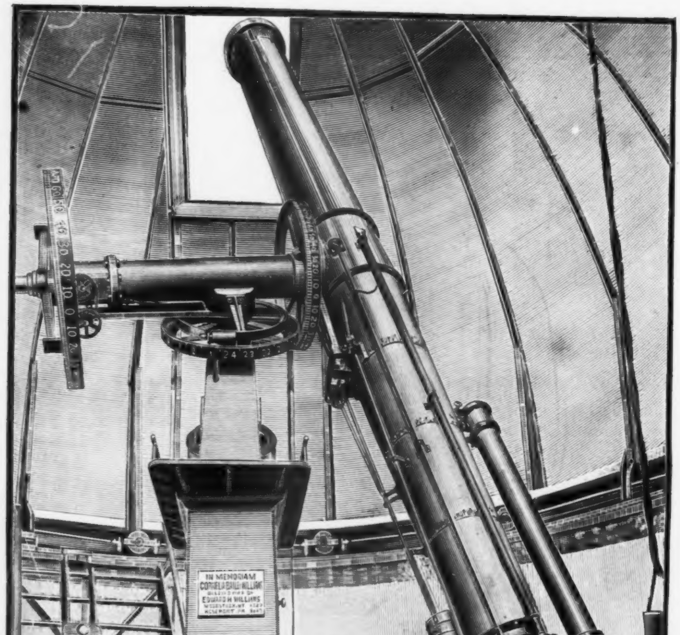

**THE WILLIAMS TELESCOPE OF GOODSELL OBSERVATORY.**

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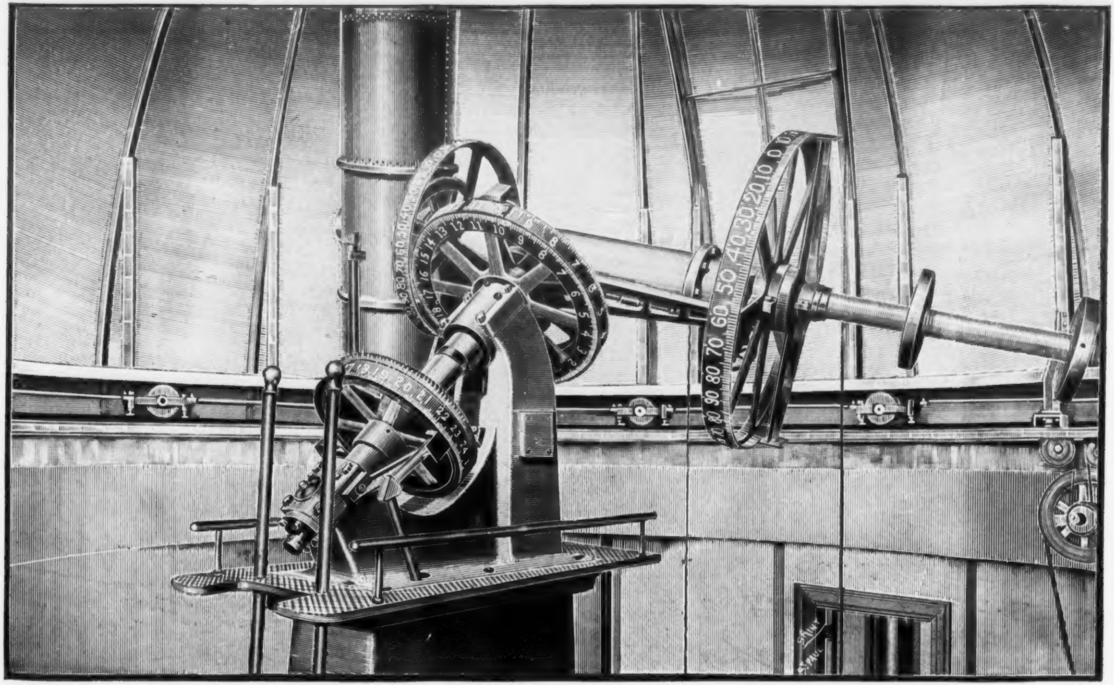

VIEW OF AXES AND CIRCLES OF THE WILLIAMS TELESCOPE.

THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE.

GOODSELL OBSERVATORY, CARLETON COLLEGE, NORTHFIELD, MINN.

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## *Investigation of the Orbit of a Body whose mass is m, that of the sun being the unit, and which is supposed to be approaching the sun with a great velocity, while it is repelled by the sun with a force directly as the masses, and inversely as the square of their distance.*

GEORGE W. COAKLEY.*

FOR THE MESSENGER.

The prevalent theory for the formation of the tails of comets is that the material constituting the tails is *repelled* by the sun. But it ought to be more distinctly recognized by astronomers than seems to be the case, that any material approaching the sun, and *repelled* by him, according to *any and every law of repulsion*, must describe an orbit CONVEX *to the sun*. The sun must be *outside the orbit*, not *within it*, so that the body cannot move *around the sun*, but can only *back up to him* within a certain distance and then depart again into space, along a curve *convex to the sun*, never again to return to his vicinity by action derived from him. This may be readily proved by supposing *repulsion* instead of *attraction*, in the same way that Newton, in the second section of his Principia, Proposition I, has proved that with *any law of attraction*, the curve described about the *center of attraction* is *always* CONCAVE *to that center*, in a *single plane*, and that *equal areas* are described in *equal times*. In the case of *repulsion* also according to *every law*, the orbit about a *center of such force* will *lie in one plane*, will be CONVEX *to the center of force* and the radius-vector will describe *equal areas* in *equal times*. The demonstration is about the same in the two cases.

The writer of this paper proposes, in a future number of THE MESSENGER, to consider the case of comets' tails, and

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how far there is any relation of repulsion between them and the sun. But he proposes to consider, as preliminary to that subject, the problem of the motion of a body towards the sun, under the influence of his *repulsion*, according to the law of directly as the masses, and inversely as the square of the distance. The writer has never met with any solution of this problem, though he has seen several statements of the result, namely: that the orbit is an *hyperbola convex to the sun.* He presumes therefore, that others would like to see the solution. The course of this investigation will closely imitate the steps of Professor James C. Watson, for the case of the sun's *attraction* of a body according to the Newtonian Law. The equations of the body's motion are derived from section 16 of Professor Watson's Theoretical Astronomy, equations (19), with proper modification for the case of *repulsion* instead of attraction. Professor Watson employs, for greater generality, three co-ordinate axes in space; but as it is only proposed to consider the orbit in its own plane, the two axes of $x$ and $y$ with their origin at the sun, and lying in the plane of the orbit, will suffice. At any moment let the body's distance from the sun be $r$, and its rectangular co-ordinates $(x, y)$, and let $\theta =$ the angle which $r$ makes with the axis of $x$. Then from Professor Watson's equations (19), the motion of the body will be determined by

$$\left.\begin{aligned} \frac{d^2x}{dt^2} &= +\, k^2(1+m).\frac{1}{r^2}.\cos\vartheta \\ \frac{d^2y}{dt^2} &= +\, k^2(1+m).\frac{1}{r^2}.\sin\vartheta \end{aligned}\right\} \qquad (1)$$

$$\text{when } \cos\vartheta = \frac{x}{r},\ \sin\vartheta = \frac{y}{r},\ \text{and } x^2 + y^2 = r^2. \qquad (2)$$

The sign + in the second members of equations (1) expresses the *condition* that the body, *m*, is *repelled*, since the force tends to *increase* the distance. If the body were *attracted*, instead of being repelled, the *minus sign* would be requisite, as in Professor Watson's equations, since the force would then tend to *diminish* the distance. Replacing $\cos\vartheta$, and $\sin\vartheta$ in (1) by their values in (2) gives:

$$\left.\begin{aligned}\frac{d^2x}{dt^2} &= +k^2(1+m).\frac{x}{r^3}\\ \frac{d^2y}{dt^2} &= +k^2(1+m).\frac{y}{r^3}\end{aligned}\right\} \quad (3)$$

From equations (3) is derived $\frac{xd^2y - yd^2x}{dt^2} = 0$, which may be written $d.(\frac{xdy - ydx}{dt}) = 0$. (4.)

The integration of (4) gives $\frac{xdy - ydx}{dt} = C = 2f.$ (5)

C, or $2f$, being the constant of integration.

Hence: $xdy - ydx = 2f.dt.$ (6).

But from equations (2) are derived:

$$x = r\cos\vartheta, \qquad y = r\sin\vartheta.$$

$$\therefore \quad \left.\begin{aligned} dx &= \cos\vartheta dr - r\sin\vartheta d\vartheta.\\ dy &= \sin\vartheta dr + r\cos\vartheta d\vartheta.\end{aligned}\right\}$$

$$\therefore \quad \left.\begin{aligned} xdy &= r\sin\vartheta\cos\vartheta dr + r^2\cos^2\vartheta d\vartheta\\ ydx &= r\sin\vartheta\cos\vartheta dr - r^2\sin^2\vartheta d\vartheta\end{aligned}\right\}$$

$$\therefore \quad xdy - ydx = r^2(\sin^2\vartheta + \cos^2\vartheta)d\vartheta = r^2 d\vartheta\,, \qquad (7)$$

Hence, from (6) and (7): $r^2 d\vartheta = 2f.dt.$ (8.)

But $\frac{1}{2}r^2 d\vartheta$ is the area described by the radius-vector, $r$, in the time $dt$. Hence, during the motion of the body, $m$, in its orbit, its radius-vector describes *equal areas* in *equal times*.

Multiply the members of equations (3) by $2dx$, and $2dy$, respectively, and add the results. Hence:

$$\frac{2dxd^2x + 2dyd^2y}{dt^2} = 2k^2(1+m).\frac{xdx + ydy}{r^3}. \qquad (9)$$

But from the last of equation (2), $xdx + ydy = rdr.$ (10)

Hence (9) becomes $d.(\frac{dx^2 + dy^2}{dt^2}) = 2k^2(1+m).\frac{rdr}{r^3}$, or

$$d.(\frac{dx^2 + dy^2}{dt^2}) = 2k^2(1+m).r^{-2}dr. \qquad (11)$$

The integral of this is:

$$\frac{dx^2 + dy^2}{dt^2} = -2k^2(1+m).r^{-1} + h. \qquad (12)$$

$h$ being the constant of integration. Equation (12) may also be written, in accordance with Professor Watson's form:

$$\frac{dx^2 + dy^2}{dt^2} + \frac{2k^2(1 + m)}{r} - h = 0. \quad (13)$$

From (5), by squaring the members, is obtained:

$$\frac{x^2dy^2 - 2xydxdy + y^2dx^2}{dt^2} = 4f^2. \quad (14)$$

And from (10), $\frac{x^2dx^2 + 2xydxdy + y^2dy^2}{dt^2} = \frac{r^2dr^2}{dt^2}$. (15)

Adding the members of (14) and (15) gives:

$$\frac{(x^2 + y^2)(dx^2 + dy^2)}{dt^2} = \frac{r^2dr^2}{dt^2} + 4f^2, \text{ or}$$

$$\frac{r^2(dx^2 + dy^2)}{dt^2} - \frac{r^2dr^2}{dt^2} = 4f^2. \quad (16)$$

Multiplying the members of (13) by $r^2$ gives:

$$\frac{r^2(dx^2+dy^2)}{dt^2} + 2k^2(1 + m).r - hr^2 = 0. \quad (17)$$

Subtracting the members of (16) from those of (17) gives:

$$\frac{r^2dr^2}{dt^2} + 2k^2(1 + m).r - hr^2 = -4f^2. \quad (18)$$

Or

$$\frac{r^2dr^2}{dt^2} = hr^2 - 2k^2(1 + m).r - 4f^2. \quad (19)$$

Hence: $dt = \frac{rdr}{\sqrt{hr^2 - 2k^2(1 + m) - 4f^2}}$, (20)

Substituting in (8) the value of $dt$ from (20), and dividing by $r^2$, give:

$$d\vartheta = \frac{2f.dr}{r\sqrt{hr^2 - 2k^2(1+m).r - 4f^2}}, \quad (21)$$

Hence: $\frac{dr}{d\vartheta} = \frac{r}{2f}.\sqrt{hr^2 - 2k^2(1 + m).r - 4f^2}$, (22)

For each value of $\vartheta$ there will in general be two opposite radii-vectores, which will meet the orbit curve in opposite points, because of the double sign of the radical in (22). One of these values of $r$ may be regarded as a maximum, the other as a minimun, for that value of $\theta$. These maxima and minima, for each value of $\theta$, will evidently be determined by making the second member of (22) equal zero. Hence:

$$hr^2 - 2k^2(1 + m).r - 4f^2 = 0. \quad (23)$$

Solving (23) as an equation of the second degree in $r$ gives:

$$r = \frac{k^2(1+m)}{h} \pm \frac{\sqrt{k^4(1+m)^2 + 4hf^2}}{h}. \quad (24)$$

The maximum value of $r$ is evidently the one with the sign $+$ between the terms, and the other is the minimum. Let $\vartheta = 0$, so that these values lie on the axis of $x$: and let $a(1+e)$, and $a(1-e)$ represent these maxima and minima respectively. Hence:

$$\left.\begin{aligned} a(1+e) &= \frac{k^2(1+m)}{h} + \frac{\sqrt{k^4(1+m)^2 + 4hf^2}}{h}. \quad (25) \\ a(1-e) &= \frac{k^2(1+m)}{h} - \frac{\sqrt{k^4(1+m)^2 + 4hf^2}}{h}. \quad (26) \end{aligned}\right\}$$

$$\therefore \quad a = \frac{k^2(1+m)}{h}, \ (27); \text{ and } ae = \frac{\sqrt{k^4(1+m)^2 + 4hf^2}}{h}$$

$$\therefore \quad h = \frac{k^2(1+m)}{a}, \ (29); \ a^2h^2e^2 = k^4(1+m)^2 + 4hf^2 \ (30)$$

But from (27), $a^2h^2 = k^4(1+m)^2$; hence (30) becomes $k^4(1+m)^2 . e^2 = k^4(1+m)^2 + 4f^2 . \frac{k^2(1+m)}{a}$.

Hence, $a(e^2 - 1) . k^2(1+m) = 4f^2$. (31).

If $a$ is considered as positive, or measured along the axis of $x$, to *the right* from the sun, then (31) proves that $e > 1$, (32); since $k^2(1+m)$ and $4f^2$ are positive. Let $p = a(e^2-1)$ (33). Hence $4f^2 = pk^2(1+m)$, (34). Equation (21) will become, by substituting the values of $h$, and $4f^2$, or $2f$

$$d\vartheta = \frac{kp\sqrt{1+m}\,dr}{r\sqrt{\frac{k^2(1+m)}{a} r^2 - 2k^2(1+m) . r - pk^2(1+m)}}. \quad (35)$$

By reduction this becomes:

$$d\vartheta = \frac{\sqrt{p} . dr}{r\sqrt{\frac{r^2}{a} - 2r - p}}. \quad (36)$$

But from (33), $\frac{1}{a} = \frac{e^2-1}{p}$; hence:

$$d\vartheta = \frac{\sqrt{p} . dr}{r\sqrt{\frac{r^2(e^2-1)}{p} - 2r - p}}. \quad (37)$$

Multiplying the numerator and denominator of (37) by $\sqrt{p}$ gives:

$$d\vartheta = \frac{pdr}{r\sqrt{e^2r^2 - r^2 - 2pr - p^2}} = \frac{pdr}{r\sqrt{e^2r^2 - (p+r)^2}}. \quad (38)$$

$$\therefore \quad d\vartheta = \frac{pdr}{er^2\sqrt{1 - (\frac{p}{e}\cdot\frac{1}{r} + \frac{1}{e})^2}} = \frac{\frac{p}{e}\cdot\frac{dr}{r^2}}{\sqrt{1 - (\frac{p}{e}\cdot\frac{1}{r} + \frac{1}{e})^2}} \quad (39)$$

But $\frac{dr}{r^2} = -\,d.\frac{1}{r}$; hence $d\vartheta = -\,\frac{\frac{p}{e}\cdot d\cdot\frac{1}{r}}{\sqrt{1 - (\frac{p}{e}\cdot\frac{1}{r} + \frac{1}{e})^2}}$ (40)

Equation (40) may also be written in the form:

$$d\vartheta = -\frac{d\cdot(\frac{p}{e}\cdot\frac{1}{r} + \frac{1}{e})}{\sqrt{1 - (\frac{p}{e}\cdot\frac{1}{r} + \frac{1}{e})^2}}. \quad (41)$$

Integrating (41) gives:

$$\vartheta = \cos^{-1}.\,(\tfrac{p}{e}\cdot\tfrac{1}{r} + \tfrac{1}{e}) \quad (42)$$

No constant of integration is needed, because $\vartheta$ will be counted from the axis of $x$.

From (42) is derived: $\cos\vartheta = \frac{p}{e}\cdot\frac{1}{r} + \frac{1}{e}$. (43)

$$\therefore \quad e\cos\vartheta = \tfrac{p}{r} + 1,$$

$$\therefore \quad r = \frac{-p}{1 - e\cos\vartheta} = \frac{-a(e^2-1)}{1 - e\cos\vartheta}. \quad (44).$$

As $e > 1$, as proved in (32), it follows that (44) is the polar equation of an hyperbola; the sun, at the pole is at the focus *outside* the orbit-branch, or at the focus *within* the opposite branch of the hyperbola from that on which the body, $m$, moves.

This orbit is necessarily *convex* to the sun, as must be every orbit described by his *repulsion*, according to *any law of repulsion.* If in (44) $\vartheta$ be assumed equal to zero, $r$ will be the radius-vector of the orbit's intersection with the axis of $x$.

Hence: $r = \frac{-a(e^2-1}{1-e} = a\frac{1-e^2}{1-e} = a(1+e)$ . This is the Perihelion distance of the orbit. As $\vartheta$ increases from $\vartheta = 0$ to $\pm\,\vartheta = \cos^{-1}\frac{1}{e}$, or $\cos.(\pm\,\vartheta) = \frac{1}{e}$, $r$ will be pos-

itive, and will increase from $r = a\,(1 + e)$ to $r = \infty$, when $\cos\,(\pm\,\vartheta) = \frac{1}{e}$. For example, suppose $e = 2$, then (44) becomes:

$$r = \frac{-\,a(4-1)}{1 - 2\cos\vartheta} = \frac{-\,3a}{1 - 2\cos\vartheta},\ \frac{1}{e} = \frac{1}{2} = \cos\,(\pm\,60^\circ).$$

If $\vartheta = 0$, $r = 3a$, . $\cos\vartheta = 1$.

If $\cos(\pm\,\vartheta) = \frac{9}{10}$,

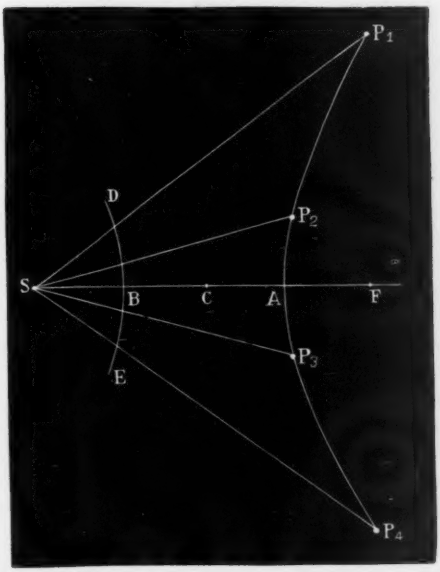
$$r = \frac{-\,3a}{1 - \frac{9}{5}} = \frac{-\,3a}{-\,\frac{4}{5}} = \frac{15a}{4} = 3a + \frac{3}{4}a.$$

If $\cos(\pm\,\vartheta) = \frac{8}{10}$, $r = 5a$ .

If $\cos(\pm\,\vartheta) = \frac{7}{10}$, $r = 7a + \frac{1}{2}a$

If $\cos(\pm\,\vartheta) = \frac{6}{10}$, $r = 15a$.

If $\cos(\pm\,\vartheta) = \frac{5}{10} = \frac{1}{2}$, $r = \infty$., or the radius-vector is parallel to the asymptote, and meets the orbit-curve only at infinity. The polar equation of the opposite branch of the hyperbola, in the focus of which the sun is situated, is evidently




$$r = \frac{+\,a(e^2 - 1)}{1 + e\cos\vartheta},$$

(45). If $\vartheta = 0$, in this branch, $r = a(e - 1)$, which is the distance from the sun at its nearest point. But the body, $m$, can never

get on to this branch since the two branches are discontinuous.

If in (44), $e = 2$, and $a = 1$, the preceding figure will represent the orbit of the body, *m*, in successive positions, $P_1$, $P_2$, $P_3$, $P_4$, as it approaches and recedes from the sun at S. $SA = 3a = 3$ is the perihelion distance; DBE is the opposite hyperbola upon which the body, *m*, cannot move. The sun S, is at the focus *within* this *concave branch*. F is the focus of the *convex branch*, or of the *actual orbit*.

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## ADDRESS AT THE DEDICATION OF THE KENWOOD OBSERVATORY.

PROFESSOR C. A. YOUNG.

It is a very great pleasure, ladies and gentlemen, to be here this evening at this dedication of this most complete and most admirably equipped of all private observatories. It reminds me very much of another Observatory which I visited some years ago where however, things were very different in a good many ways. It was the old Observatory at Peking, at one corner of the city upon its wall, which is about sixty feet high and so wide on top that four carriages can drive abreast around the city. In a little enclosure at the base of the wall are two ancient instruments, more than six hundred years old, one of them an equatorial in principle very much like this instrument before us, but of course carrying no telescope; the other is a large astrolabe. These two instruments were brought from Samarcand by the Tartars when they captured the city under Genghis Khan. In the Observatory proper, upon the top of the wall there are mounted a number of other instruments, more modern than these, though still very old. Some of them were brought from Paris about 1660, and two or three were made in China. They are all mounted in the open air, and are all in condition to be used, and might be used with only slight repairs. I presume Mr. Brashear could put them in two days into such condition that they could be used as well as ever. They were erected before the days of the telescope, and designed for use in the methods of the "old astronomy."

They were made for the purpose of observing simply the positions and motions of the stars.

In those days astronomy was believed to be an exceedingly "useful" science with a most immediate and direct bearing upon human affairs. Mr. Wells Williams was with us at the time of our visit, and translated for us the mottoes upon the tablets that hung upon the walls. On one of these tablets the legend was this: "By observing the constellations we fix the times," and "times" means opportunities. Watch the stars, and from them, according to the belief which then prevailed, you can tell whether it is a good time to do this thing or that. A second tablet read: "By observing the motions of the stars we apprehend what is suitable to the seasons"—the same idea in a little different form. And the third was: "By reverentially conforming to the revolutions of the heavenly bodies we avoid disaster." 'Disaster,' you know, is a purely astronomical word in its derivation. The point is that then astronomy was considered a directly 'useful' science. As the world has progressed, I suppose that we must give up that idea, to a very considerable extent. The old astronomy really had, and still has certain important practical uses. The great observatories of the world, Greenwich, Paris, Berlin, were founded especially to watch the motions of the moon and stars so as to provide means for determining the longitude at sea. Herein, however, lies about all the pecuniary value of astronomy so far as we know at present. It is not true that the stars exert any notable influence upon our affairs, or that their observation can be made directly profitable.

A new astronomy has sprung up, and now, instead of studying simply the motions of the heavenly bodies astronomy has come to pay very much more attention to the nature and character of them, and we are trying to utilize the stars, to a certain extent as laboratories and instruments for researches which we cannot manage in our terrestrial domes. In the stars we find higher temperatures and different conditions from any that are attainable on the earth, and it seems highly possible that we may thus learn something from the stars:—their light may bring us information that may be useful in terrestrial investigations.

Still I should be dishonest if I undertook to say that I

really thought that even in this line there was very much money to be gotten from astronomical investigations. The great benefit, the great use of astronomy to the world, as I understand it, is intellectual;—culture to the individual and to the nation,—a very different thing from money—and a nobler. It is true that we must have our bread and butter *first* and earliest—that has to be provided for, just as must the foundation for the building, but the noblest part of the building is not the foundation. I know of no other science in which we so learn to look out of self and so far beyond self, and into the great outside universe—none that so promptly puts the man into his true relations of space and time and power. It is not so much knowledge—knowledge is power, good, excellent—but it is the LEARNING and the KNOWING after all that develop the man, and perfect the image of the Creator within him.

I am not going to take any great amount of time this evening, ladies and gentlemen, for I have nothing that really deserves to be called an address to present to you. Mr. Hale, has kept me so busy that I have not had time to write out anything; he has kept me interested and at work in one way or another ever since I came here. I never enjoyed two days in my life more than I have these last two, for I have seen science developing in the particular directions that have a special interest for me. Some years ago, if I may be allowed to make another personal allusion, I was out on the Mountains at Sherman Station, on the Union Pacific Railroad, observing the spectrum of the sun for the purpose of trying to find out what astronomical advantages were attained by getting up eight thousand feet above the sea level, and thus leaving a large portion of the air below. A government expedition had been organized of which I was a member, and I took out a nine-inch telescope —not so large a one as this is by considerable—and worked away upon the spectrum of the sun with my human eyes as well as I could. One of the most notable results was the discovery that in the solar spectrum the two great broad black bands known as H and K had each a bright line running through its center, whenever the telescope was directed at the edge of the sun or at the neighborhood of a sun-spot. This being so, it ought to be possible to study the promi-

nences through these lines just as we do through the red C line of the solar spectrum. I did not think at that time that it would probably be practicable, though it might be possible, if our eyes were 'blue' enough, *i. e.*, if they were sensitive enough to that kind of light. Now here at the Kenwood Observatory, instead of using *eyes*, which do not see that kind of light very well—at least my own eyes do not—Mr. Hale uses photography, and with this admirable apparatus (the finest certainly for this purpose in existence), he has found that it is easily possible to photograph the bright lines in those two dark bands of the spectrum. This means that things which were very difficult to see, even with the help of mountain air, and the utmost protection to the eye, can be photographed here in Chicago perfectly and easily. I saw it done Saturday and again to-day, and I am confident that Mr. Hale is going to succeed in procuring pictures from day to day of the cloud-forms about the sun.

I suppose you know what I am talking about. The sun itself is a great ball of heated vapor, covered with an outside shell of cloud, which is the photosphere,—the sun we see. But over-lying the photosphere there is a stratum of gases heated like a sheet of flame that we call the 'chromosphere'; and reaching up to elevations sometimes four hundred thousand miles in height—that is very rare, but ordinarily, thirty, forty or fifty thousand miles—there are great clouds or flames called the solar prominences composed of heated hydrogen, and other gases mingled with it. They are wonderfully beautiful objects, but can be seen (except at eclipses) only by the help of the spectroscope; and they change so rapidly that it is extremely difficult to delineate them correctly by eye and hand. So you can imagine that astronomers greet with enthusiasm the prospect of securing their photographs.

There is also a great deal of special interest of a different sort connected with the H and K bands of the spectrum.

I am not going to undertake to explain them. I do not think people yet know all their secret. But the fact is that these two bands,—at least two black bands in just that position in the spectrum,—are found in the light produced by an electric spark as passed between the poles of calcium: two carbons are dampened with a solution containing

calcium, and immediately when the electric arc passes between them, two bright lines appear that correspond precisely to the position of the middle of these bands in the solar spectrum. Hence it has been supposed very naturally, —and very likely the supposition is true, that calcium is the material that causes these bands in the solar spectrum. Still there are difficulties. It is strange, if that is so, that other lines of calcium do not show themselves in these solar prominences. So that if the H and K lines are really due to calcium, we have a puzzling problem. The calcium which produces H and K, is calcium in some different condition, or, at least, in some different state of excitement from the calcium which produces the hundreds of other calcium lines in the spectrum. I do not know that I even dare say that. It is *behaving* differently, at any rate, from the calcium that we work with on the earth's surface.

Then again we meet a very singular thing when we come to photograph the spectra of the great white stars. We find in the lower part of the spectrum a series of dark bands that correspond to the well known lines of hydrogen; and when we come to the H band we find there a wide dark black band, but K is absent; then in the ultra-violet there is another series of hydrogen lines; and all of these, including H, are spaced as regularly as the teeth of a cog-wheel. Evidently, according to that, H would seem to be a line of hydrogen, and I do not yet feel sure whether this H line that we see in the spectrum of a solar prominence is hydrogen or calcium. It may be both. I think Mr. Hale will be likely to find out by and by, and when he has found that out, he is likely to have opened a road to some new results with reference to the molecules of hydrogen and calcium and other substances; for this atmosphere of our sun is a very strange thing in many ways. If the earth is a chip of the old block, and I suppose it is, the sun ought to have oxygen in it, which composes over half of the mass of the earth: there is not a trace of oxygen in the sun that we can be sure of. You ought to have nitrogen there, the main constituent of our atmosphere: we do not find it. We ought to have chlorine there but it does not appear. We do find nearly all of the *metallic* elements there, but these non-metallic elements for some reason do not reveal themselves, if they are really

there. It is quite likely that further researches of the kind to be prosecuted here will give us light in that department of physics; and I am sure that if we do learn in this way something about the relations of the ultimate molecules of matter, it will be exceedingly valuable scientific information. It may even turn out to have a 'bread-and-butter value' as bearing upon chemical theories, and, sooner or later it may affect human interests in many ways: still I cannot promise you that it will.

This is not by any means the first of the observatories of the new astronomy in the world, or even in this country. There have been predecessors in America and Europe, and there are now two observatories in Europe that are, in many respects, more fully equipped than this,—not more perfectly, however, for the one object that is just now aimed at. In Germany they have the great Astrophysical Observatory at Potsdam. Possibly some of you may have seen it: it will well repay a visit. During the last two or three winters they have been most successfully at work upon the spectra of the stars. They have done work upon the solar spectrum also, but only along old lines—no special advances have been made with respect to solar chemistry at Potsdam. Then there is the great French observatory at Meudon, which, when complete, will be perhaps on a still grander scale. They are proposing to have a great twin telescope, each of the "twins" having an object glass two feet in diameter, with a tube about thirty feet long, the two mounted side by side. With them they expect to go on both with photographic and spectroscopic investigations.

In England there is no National Physical Observatory. A certain amount of physical work is done at Greenwich, but that is a mere by-play to the main business of the Observatory, which is watching the motions of the planets and of the moon, and making star-catalogues. The private observatory of Dr. Huggins, however, must not be passed unmentioned: it was the birthplace of spectroscopic astronomy and is still in most active and effective operation. Mr. Lockyer also has a semi-private establishment for spectroscopic work; and Common and Roberts and one or two others have fine photographic telescopes.

I think, that the earliest of the physical observatories in

this country was that of Mr. Rutherfurd of New York, and, in a good many ways, this Kenwood Observatory is its direct descendant. It was there that the first successful photographs of the moon were made. Some daguerrotypes had been obtained before at Cambridge with the old telescope, but that instrument was not designed for photographing, and did not give very perfect results. But in the sixties—Mr. Rutherfurd succeeded in getting photographs of the moon that, until within the last three years, had no superiors,—no rivals even, among those that have been made elsewhere. They remained in full possession of the field for at least fifteen years. But lately, both at Paris and at the Lick observatory, and perhaps at Cambridge, the new instruments and methods have gone beyond his best. You have seen down stairs a photograph made at the Lick Observatory.

Rutherfurd also took up the subject of Spectra, and ruled the first good "grating." I have to put in the qualifier "good," because gratings had before been used in Europe. Fraunhofer used a grating in some of his observations as early as 1820;—an actual grating of wires spaced one hundredth of an inch apart. And later Nobert—many of you have heard of him—succeeded in ruling lines very close together,—nobody has ever done better in that respect, and he made a few small plates where a space of about half an inch square was ruled with fine parallel lines, which ably used in the hands of Angstrom and others have yielded classical results.

Mr. Rutherfurd at first ruled a few gratings upon glass and afterwards substituted speculum metal. I remember well the first one that I ever saw about 1867, and a great astonishment it was to me. It was abont half an inch wide, and the lines were about an inch long; and it was an absolute amazement to me to find that it would give a spectrum vastly better than any prism or even than a train of five or six prisms. Indeed on going to Europe in 1870, in connection with an eclipse expedition, I found that many English astronomers and physicists whom I met then supposed that you could merely see the colors of the spectrum, in a diffraction grating, and had no idea that you could see the finer Fraunhofer lines. Later, Mr. Rutherfurd

succeeded in ruling magnificent gratings in which the lines were about an inch and a half long, and the ruled space was one and one-half inches square. About eight or ten years ago Professor Rowland, of Baltimore, constructed a machine with which he rules lines four inches long, and covers spaces six inches wide with fine, even, parallel lines about one-fourteen thousandth of an inch apart. Such a grating makes a magnificent spectrum, and downstairs there is a beautiful specimen of a grating of this kind that is ruled upon a slightly hollow surface. And here, (pointing to the spectroscope) is a five-inch grating, as it is called, in the round box at the lower end of the spectroscope, which gives the most beautiful spectra I ever saw.

This explains what I mean by saying that this Observatory is a lineal descendent of Mr. Rutherfurd's. It is the diffraction grating that furnishes the analyzing power that breaks up the sunlight and makes possible the investigations that Mr. Hale is taking up. The telescope, too, is almost the same size as Mr. Rutherfurd's though longer; and it is much handsomer, for thanks to the abilities and workmanship of its makers, Mr. Brashear and Warner & Swasey, things are finished in a little more elegant style than in a machine which like Mr. Rutherfurd's,* was constructed, piecemeal, for the purpose in hand at the moment, a little one day and a little more the next.

Then came the Observatory of Dr. Henry Draper, who went into stellar spectroscopy. He was a professor in the University of New York, and was fortunate enough to marry a very lovely and, at the same time, very rich lady, who was extremely interested in the line of work that he took up, so that he was enabled to go on with his researches in an admirably fitted Observatory that he erected at Hastings-on-Hudson. His death in 1881 or '82, was, I think, one of the greatest losses that American science ever experienced. At the time he had just entered upon a course of conquest; he had begun to photograph the spectra of the stars with a success which had never been attained before.

* Mr. Rutherfurd's Observatory was discontinued some years ago, on account of the owner's failing health. The telescope and most of the apparatus, was given to the Observatory of Columbia College, where it is now mounted.

Since his death his work has been taken up at Cambridge. Mrs. Draper has turned over the instruments to the Observatory there, and has provided a liberal income—six or eight thousand dollars a year, and more when necessary—to aid in carrying on investigations in this line of stellar spectroscopy.

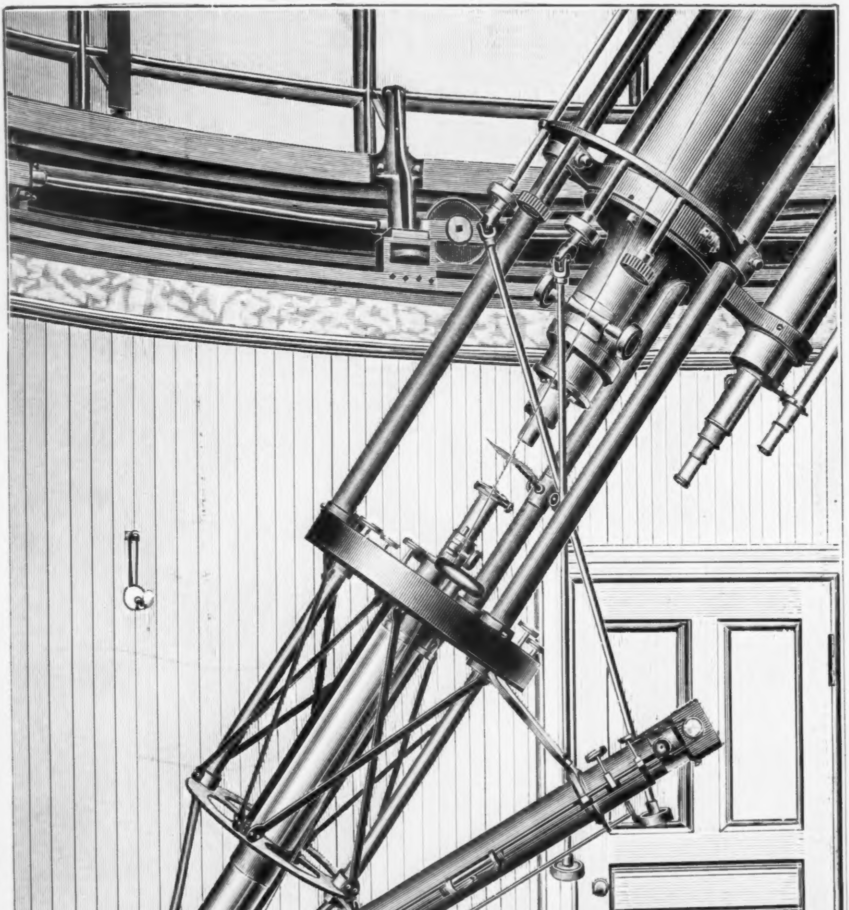
And now starts up this new Observatory in the line of solar work, and I am very confident that, if Providence is kind and permits Mr. Hale to go on, as there is every reason to hope will be the case, we shall soon have splendid results from it.

I will add that just before I left home I received notice that at Washington they are erecting an Observatory (which will be under government auspices) for astronomical physics, under the charge of Professor Langley. Its work will be mainly with a different instrument, the bolometer, for the purpose of measuring the distribution of heat over the surface of the sun, and moon, and possibly the heat from the stars. I do not think Professor Langley yet believes that stellar heat can be measured in this way, but I half think that he will succeed better than he expects.

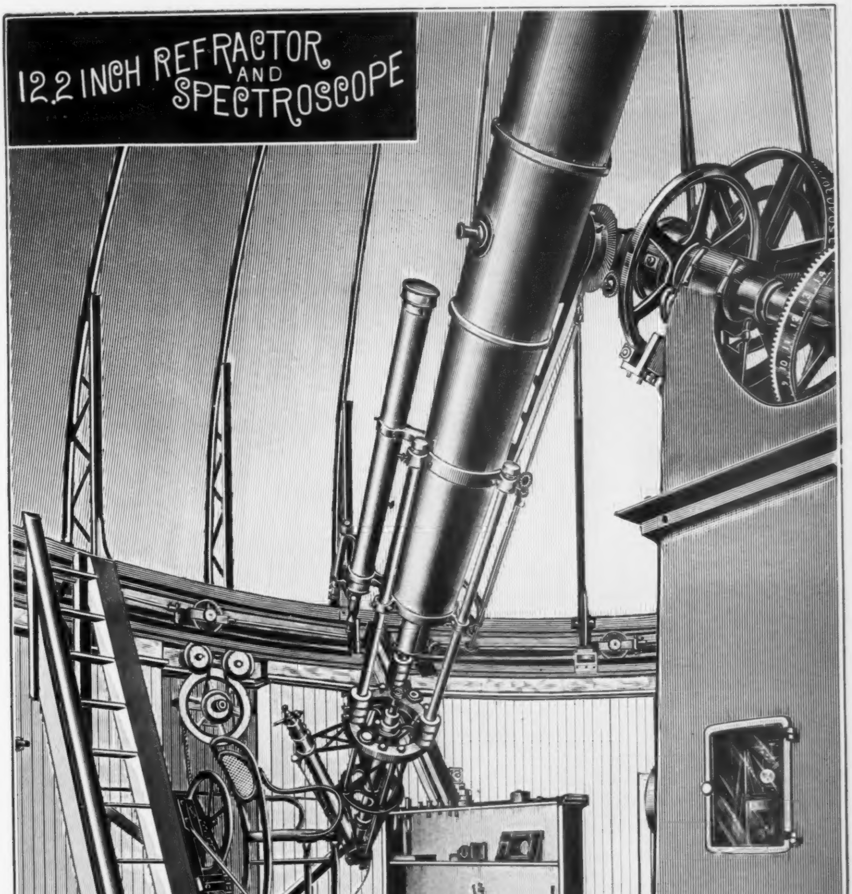
And now let me close with a few words as to the relative advantages of public and private observatories.

I am myself connected with an observatory which is a department of a college and certainly I have always been treated with the greatest liberality and freedom, but public institutions, are under boards of trustees who are administering trust-funds, and have their hands, to a certain extent, tied, and do not feel quite at liberty to try doubtful experiments. But here if Mr. Hale thinks it is well to try an experiment, with one chance in ten that it will prove a success, he is very likely to try it, and he has nobody to answer to if it fails, and that is a great advantage that a private institution, like this, has over a public one—the observers may use their instruments and funds in any line they please. They have the liberty of scientific exploration, and it is a great liberty. In public observatories we are and ought to be very much limited, and only carry on investigations which are reasonably sure to prove beneficial and fruitful. But I say this here because there are a good many private gentlemen present, who I presume, are interested more or less in


THE KENWOOD
PHYSICAL OBSERVATORY
CHICAGO.



THE SOLAR SPECTROSCOPE ARRANGED FOR PHOTOGRAPHING THE SOLAR PROMINENCES.


12.2 INCH REFRACTOR AND SPECTROSCOPE

science, and I am sure that private investigators in the scientific line have at least one very great advantage over public institutions. The fact is, that a large number of the most important astronomical and scientific discoveries have been made by those who are called amateurs, but "amateur," rightly interpreted, means, what it ought to mean and not what it is commonly understood to mean—it means a man who is a "lover" of the science, as he would be of a woman: devoted to it, as he would be to his wife: willing to spend and be spent for it. It does not mean a "dilettante," who delights a little with it—fools with it, as we say, in the language of college boys. The true "amateur" is one who is ready and willing to devote himself to the science he has chosen. And so from the character of my young friend here, and from your warm interest in him and his work I have my liveliest anticipations aroused and expect rich results. This has been one of the happiest occasions of my life—the three days that I have spent here. (Applause.)

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## THE KENWOOD PHYSICAL OBSERVATORY.

GEORGE E. HALE, DIRECTOR.

FOR THE MESSENGER.

The Kenwood Physical Observatory had its inception in a spectroscopic laboratory erected in Chicago in the summer of 1888. The addition of a tower and wing during the winter of 1890-91 brought the building to its present form, and it now includes a reception room, library, equatorial room, "slit room," "grating room," photographic dark room, general laboratory, and workshop, [Plate 1]. The grating room contains a four-inch concave grating of ten feet radius of curvature, mounted in the manner employed by Professor Rowland. A shorter girder allows the use of a grating of only five feet radius, in cases when the light source is too faint to admit of the highest dispersion. Sunlight is furnished by a heliostat on a pier some distance to the north of the building, while a Weston dynamo, driven by a gas engine of six horse-power, supplies the direct current used in spectroscopic studies of the electric arc. An alternating current of 52 volts is also supplied by the

Hyde Park Thompson-Houston Company, and this is especially useful in producing heavy electric sparks with a large induction coil, and in lighting the whole Observatory with incandescent lamps. A set of thirty-five Julien storage cells can be charged by the Weston machine, and used when desired.

The mounting of the equatorial was finished in March, 1891, by Messrs. Warner and Swasey, and the excellent 12.2-inch object-glass, figured from Dr. Hastings' calculations by Mr. J. A. Brashear, was in place and ready for use early in April, 1891 [Plate II]. The spectroscope is of very large size, and was also made by Mr. Brashear [Plate III]. A frame of strongly braced steel tubing carries the collimator and observing telescope, which make with each other a constant angle of 25°. The objectives are exactly alike, of 3¼ inches clear aperture and 42½ inches focus, corrected for work in the visual region. The grating is a 4-inch flat, and in many respects is the finest ruling I have ever seen. In addition to the grating there is a 30° white flint prism, silvered on the back, which is used in photographing the spectra of the fainter stars. The large size of the spectroscope, and the necessity of a perfectly rigid attachment to the equatorial, have caused us to mount the spectroscope and tube as if in one piece, the declination axis coming at the center of their combined lengths. As the object-glass of the equatorial has a focal length of 18 feet, the total length of the combination is 22 feet 9 inches. The mounting is built very large and heavy, and carries also a four-inch Clark telescope and a small finder. The rate of the driving clock can be controlled by electric connection with an excellent Howard clock.

As my recent photographic investigations of solar prominences and their spectra have shown the necessity of employing specially corrected objectives in a continuance of the research, it has been decided to supply the telescope with a photographic object-glass of exactly the same aperture and focal length as the present visual glass. A double tube will replace the single tube now used, and the object-glass will be so supported that either one may be used on either tube. The spectroscope will thus form a part of the instrument, as before, and the eye-end of the second tube will be

left free for the attachment of any desired apparatus, such as an amplifying lens and camera for photographing sun-spots on the Janssen method. Various improvements of the spectroscope will be made by Mr. Brashear, one of the most important being the construction of a new device of the writer's for prominence photography. A new observing telescope, with an objective of about six feet focus corrected for the K region is to be constructed for the spectroscope, and used for further study of the prominence and chromosphere lines recently discovered. Mr. Brashear also has the order for the twelve-inch photographic object-glass, for which the whitest possible flint will be secured from the Jena factories, while the crown will be furnished by Mantois. The writer will spend some time visiting the European observatories in search of new ideas in apparatus and methods of work, which will be embodied in the improved instruments.

The Kenwood Physical Observatory was dedicated to scientific research on June 15, 1891. Addresses were made by Professor C. A. Young, Professor G. W. Hough of the Dearobrn Observatory, Mr. J. A. Brashear, President E. D. Eaton, of Beloit College, and several others. Professor Young's address will be found in full on another page. The Observatory has been incorporated under the laws of the state of Illinois, and its control is vested in a board of trustees. The plan of work laid out for the future includes a thorough study of solar phenomena, and particular attention will be given to spectroscopic investigations of the spots, chromosphere, and prominences.

BROOKLYN, N. Y., June 29, 1891.

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## THE MOTION OF THE DOUBLE STAR, $\beta$ 612.

S. W. BURNHAM.

For THE MESSENGER.

I discovered this pair in 1878 with the refractor of the Dearborn Observatory, and measured it on three nights with that instrument. It was also measured by Hall during the same year, and several years later by Engelmann. I have lately made another set of measures with the 36-inch,

and a comparison of all the observations appears to show a very rapid movement in the angle. These measures are as follows:

| | | | |
|---|---|---|---|
| 1878.33 | 56°.1 | 0″.23 | β 3n |
| 1878.96 | 60 .5 | 0 .24 | Hl 4n |
| 1884.02 | 52 .4 | 0 .28 | En 5n |
| 1891.28 | 191 .1 | 0 .28 | β 3n |

This is a sixth magnitude star (B. A. C. 4559), and the components are so nearly equal that all of the measures, so far as the observations are concerned, might be in the same quadrant. That disposition of them, however, would seem to be improbable since it would require a large error in some of the measures. The two sets of measures in 1878, giving 58°.3 for the position-angle, by their agreement determine the place at the time with substantial accuracy; and measures on three nights this year, with the large refractor, must give the place with very little error. With all the angles in the same quadrant, the motion would be practically uniform, as there is but little change in the distance. If the first and last measured angles are assumed to be correct, then there would necessarily be an error of about 15° in Engelmann's angle, which is not probable in the work of this excellent observer. The first three measures all agree in placing the smaller component in the first quadrant, while in the later measures it was obviously in the third quadrant. If this arrangement of the angles is correct, the apparent ellipse is a very extraordinary one, since the primary star must lie very near its circumference in order to satisfy the law of equal areas in equal times, and, notwithstanding the rapid angular motion in the last seven years, the period must be rather long, probably more than one hundred years. In this case the change from this time will be comparatively slow. The measures of one more year will probably show conclusively whether any mistake has been made in the relative magnitudes of the components.

The place of this star (1880) is:

R. A. $13^h\ 33^m\ 40^s$
Decl. $11°\ 21'$

LICK OBSERVATORY, June 15, 1891.

## THE CAMERA FOR CELESTIAL PHOTOGRAPHY.

BY S. W. BURNHAM, LICK OBSERVATORY.

Every possessor of a good rectilinear lens and the ordinary landscape camera may not be aware of the fact that he has the best kind of an instrument for making pictures of the sky. The requirements in a lens for landscape photography are exactly the same as those which have to be considered in the department of celestial photography. About the same angle of aperture is desirable, and in a general way, the same class of lens as in landscape and out-door photography. To get a satisfactory picture of a portion of the heavens at night, as we see it with the naked eye, the picture should include an angle of not less than 30° or 40°. There is this difference between terrestrial and celestial pictures: in the former we rarely get as much as we can readily see with the naked eye from the point where the picture is taken, while in the latter we can easily get infinitely more by prolonging the exposure. If the exposure is much extended in daylight work, the plate is hopelessly fogged, and instead of increasing the details in the darker portions of the picture, nearly all delicate details are lost, and the negative becomes flat and valueless; but with the plate exposed to the dark sky of a clear night, where the light emanates only from minute points, the exposure may be continued for hours, and when the plate is developed it will be almost clear glass except where those specks of light have made their impression. Negatives of this character possess this unique peculiarity, that no matter how long the exposure may be continued, they are always under-exposed with reference to the great majority of the stars shown; and at the same time, unless the exposure is very short, they are over-exposed with regard to the brighter stars visible to the eye. The longer the exposure, the more stellar points we get on the plate, and this could probably be continued far beyond the time one would be likely to give to the following of the stars as they move across the face of the sky.

Almost every amateur photographer has a lens and camera well adapted to do this work, but unfortunately not many have the means of mounting such an instrument so as to hold

the stars fixed on the plate during the necessary time of the exposure. For this purpose an equatorial mounting, driven by clock-work, is indispensable. In other words, the photographer must have the use of an equatorially mounted telescope of some kind, with a driving-clock so adjusted as to compensate for the revolution of the earth on its axis, and keep the camera and the stars relatively fixed, the telescope itself being used as a sort of a finder, to keep the star, selected for following exactly in the same place in the instrument by changing the position of the telescope and the camera attached to it with the slow motions with which all such instruments are provided. No driving-clock, however perfectly made and adjusted, can be trusted to hold the star exactly on the fine wire or spider-web in the focus of the telescope for any considerable length of time. This must be done by watching the finder, and whenever the star shows a tendency to get ahead or fall behind the bisecting wire, bringing it back to position by the slow motions which move the instrument independently of the clock. Everything depends on careful following and keeping the images of the stars all the time on exactly the same places on the plate. If this is not attended to, the stars will be elongated in the direction of their motion across the plate, and the negative will be unsatisfactory for any purpose. In addition to this, the fainter stars will be lost by the images spreading over the greater area on the plate. If the following is perfect, and the camera is accurately focussed, the smaller stars will be exceedingly minute specks, and if the exposure is an hour and upwards, there will be thousands of these tiny points scattered over the plate where perhaps only a score or two of stars are visible to the naked eye, while not a dozen of them could be seen at all on the ground glass of the camera.

Of course not many photographers have the necessary facilities for making pictures of this kind. If, however, some friend or good-natured astronomer has a small telescope of the kind referred to, which can be made available, the thing is easily managed. The camera can be strapped or tied to the tube of the telescope in a few minutes, and then everything is ready to proceed with the exposure. The camera should be focussed previously with the utmost care, using the full aperture on a well-defined distant object, and then

marked or clamped in such a way that nothing can be changed when the camera is attached to the telescope. It is almost indispensable that the full aperture should be used if the exposure is to be continued long enough for the fainter stars, as otherwise the time would be greatly increased, with very little corresponding gain. Any good rectilinear lens will give sharp images over a sufficient portion of the plate, provided it is accurately focussed. In most uses of the lens this is not an important matter, because any ordinary error is corrected by the use of stops, but in stellar pictures a small error in the position of the lens will utterly spoil a plate which otherwise would have been entirely satisfactory.

It will be found very convenient to have one of the common simple shutters attached to the camera lens, with a tube and bulb running down to the eye-piece, so that the lens can be closed in an instant if anything goes wrong. The clock may need winding, and the dome shifted from time to time, and, although with a good driving-clock the observer can leave the instrument long enough to attend to such matters, it is safer to be able to shut off the light in the event of the clock stopping, or any accident occurring, Then the instrument can be brought back to the original place, and when everything is all right, the exposure continued as long as may be desired.

It is perhaps now generally known that the exquisite pictures of the Milky-Way, and other portions of the heavens, made by Professor E. E. Barnard of the Lick Observatory, were made with an ordinary portrait lens tied to the tube of a six-inch telescope. These pictures have never been excelled by anyone ,and rarely, if ever, equalled. They show, as pictures taken with no photographic telescope could, the wonderful structure of the invisible heavens with the millions of stars lying beyond the reach of the unaided eye. The number of individual stars shown on a single 8 × 10 plate, and that of a region not in the Milky-Way, and in which but few stars are seen with the eye, is estimated to be not less than 60,000. This required an exposure of about four hours, using an aperture of about one-sixth of the focal length of the lens. Such pictures require the greatest care in making the exposures, and extreme skill in developing the plate to get the best results. But very interesting pictures

can be made in less time. With an hour or an hour and a half, a vast number of telescopic stars will be shown, and such a negative of a prominent constellation, like Orion or Ursa Major, will repay the amateur for all the trouble it may cost to get it. Lantern slides from such negatives are more wonderful and interesting than any other stellar photographs. When thrown upon the screen, it is difficult for many to believe that such a wilderness of stars could be really photographed with a lens, through which not one in a thousand could be seen on the ground glass.—*From Anthony's International Annual of Photography, 1891.*

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## ON THE ORBITS OF METEORS.

W. H. S. MONCK, DUBLIN, IRELAND.

FOR THE MESSENGER.

The recent work of Dr. Kleiber on the orbits of meteors is probably the fullest that has yet appeared. It has two disadvantages: first that it is written in Russian with the exception of an English abstract (on which alone, together with the figures, I have relied) and secondly that it is full of typographical errors which are by no means completely corrected in the table of errata. The computation of orbits corresponding to Mr. Denning's 918 radiants, however, was a gigantic task, and can hardly fail to prove an useful one. Mr. Denning's Catalogue, I should observe, is not very suitable for drawing inferences as to the properties of radiants generally, because it contains numbers of determinations of the same radiant in different years. But when we come to deal with the results numerically we often find contrasts much too great to be accounted for in this way.

I cannot find that Dr. Kleiber's results afford any explanation of stationary radiants, and their existence appears so certain as a fact (if, indeed, all radiants are not stationary) that this defect seems to me to show that the current theory on the subject is incomplete—in other words that the motions of meteors in the air depend in part on some cause which has not yet been detected. I suggested the impulse of the air on the meteor as the cause which had been neglected, but this does not seem very satisfactory. The problem has yet to be solved.

Dr. Kleiber's results were supposed to confirm the shifting of the Perseid radiant which Mr. Denning had inferred from his observations. This seems somewhat doubtful. Dr. Kleiber's idea is that the Perseid meteors form a ring having a definite orbit in space. In this case the elements $i$ and $\pi$ — ☊ in the computed orbits ought to be constant—which condition Dr. Kleiber thinks Mr. Denning's Perseids fulfil "tolerably well." It is at all events not more than "tolerably" well, seeing that for the first radiant in his catalogue which Mr. Denning calls a Perseid the value of $i$ is 107°.9 and of $\pi$ — ☊ 162°.1*, while for the last Perseid radiant the corresponding values are $i = 113°.5$, $\pi$ — ☊ = 142°.7. It may be worth noting that at an ascending node, where the orbit passes from the S. to the N. of the ecliptic, the meteor-tracks, if projected backwards, must intersect to the S. of the ecliptic; while for a similar reason at the descending node they must intersect to N. of it. Hence a northern radiant (a radiant with N. latitude) implies that the meteor is seen at the descending node, and a southern radiant implies that it is seen at the ascending node. An observer in the latitude of Bristol naturally sees a larger number of meteors belonging to northern than to southern radiants; and of Mr. Denning's 918 radiants only 96 appear to be southern. This peculiarity, however, probably depends on the observing station and does not indicate any law of the distribution of radiants.

If I walk along a train-line I meet a larger number of trains than those which overtake me, and for the same reason we might expect to encounter more meteors whose motions were retrograde than those whose motions were direct; the difference being more marked at small inclinations. Dr. Kleiber's Catalogue, however, shows the contrary. Orbits with direct motion predominate especially at small inclinations. For inclinations of less than 10° more than two-thirds of the meteors are direct. This reminds us of the comets of short period whose motions are in almost all cases direct and their inclinations small, and meteors of this class are worth watching to see whether they exhibit a six or seven years' periodicity like the comets in question.

* Whether designedly or by a typographical error Dr. Kleiber omits the letter P. (Perseid) after this radiant.

The Catalogue exhibits some very remarkable features with regard to the value of $\pi - \Omega$. Among 918 radiants we should expect to find about 150 with a value of 0° to 60° for $\pi - \Omega$. There are in fact only 17. But this is not all; 15 of the 17 are among those in which the meteors are seen at the ascending instead of the descending node. In no case where the meteors are at the descending is $\pi - \Omega$ less than 36°. Moreover the same deficiency occurs for meteors at the ascending node when the value of $\pi - \Omega$ is between 180° and 240°. Nor does the deficiency cease at these points. For values of $\pi - \Omega$ between 60° and 120° we have only about 60 orbits instead of 150, and in more than one-half of these 60 the meteors were seen at the ascending node. For values of $\pi - \Omega$ between 300° and 360° there is also a deficiency (the number being again about sixty), but the great majority of these showed meteors at the descending node. There is, of course, a corresponding crowding for values of $\pi - \Omega$ between 120° and 300°. The result appears to be that meteors are not seen unless the node is tolerably near the perihelion. In fact, if V stands for the node which we are considering, the chance against seeing any meteors is enormous if $\pi - V$ lies between 180° and 240°, while it is considerable for all values of $\pi - V$ between 120° and 300°. I fail to see any physical cause capable of explaining this singular state of things, and can only suggest that the force (whatever it be) that has been neglected in these computations has the effect of making the node appear to be nearer to the perihelion than it really is.

Another remarkable fact is that during the first six months of the year, when the earth is receding from the sun, the direct orbits out-number the retrograde in the proportion of four to one, while the retrograde orbits are more numerous during the latter half-year.

Having touched on the question of meteoric rings I may mention that such rings appear to be more strongly indicated by Dr. Kleiber's figures in some other cases than in that of the Perseids. Here is one for instance:

| No. in lat. | Radiant. | $i$ | $\pi - \Omega$ | Date. |
|---|---|---|---|---|
| 119 | 272 + 21 | 92.9 | 236.9 | Apr. 25. |
| 208 | 329 + 36 | 92.4 | 237.4 | July 12. |
| 493 | 16 + 54 | 94.0 | 243.1 | Sept. 5. |
| 521 | 20 + 56 | 90.6 | 240.2 | Sept. 13. |
| 672 | 70 + 65 | 94.0 | 243.7 | Oct. 15. |
| 812 | 140 + 65 | 87.0 | 239.7 | Nov. 25. |
| 873 | 161 + 58 | 90.9 | 237.2 | Dec. 9. |
| 909 | 177 + 49 | 92.8 | 243.0 | Dec. 28. |

This of course is only intended as a specimen. There would seem to be a grand ring with a radiant situated not far from the pole of the ecliptic into which most of the Draconids enter.

In conclusion I may notice that as the tangent at the perihelion is perpendicular to the line joining the perihelion to the sun, any force perpendicular to the line joining the meteor to the sun will make the perihelion seem nearer than it is. But the earth's orbit being nearly circular a force directed along it will be nearly perpendicular to this line. Consequently a force directed along the earth's orbit, and neglected by the computer, will, I think, account for the peculiar features exhibited by Dr. Kleiber's Catalogue; and perhaps the conjecture which I hazarded as to the effect of the impulse of the air upon the meteor may not be so wide of the mark as my mathematical friends imagine.

## PHOTOGRAPHING WITH A NON-PHOTOGRAPHIC TELESCOPE.

PROFESSOR E. E. BARNARD, LICK OBSERVATORY.

We are familiar with the fact that when a ray of white light passes through a prism, it is separated into a band of brilliant colors, red at one end and blue or violet at the other. This is called a spectrum. It has been found that different portions of this spectrum have vastly different effects upon the ordinary photographic plate when exposed to its action. This effect is called *actinic energy*. The greatest actinic energy comes from the ultra violet, in the region of the hydrogen line G. It diminishes rapidly in going down the spectrum, and ceases near the line F. Still further down the spectrum occurs the brightest part in the yellow near the sodium line.

All lenses act more or less as prisms, and the light passing through them is separated into the primary colors, and these are each refracted differently, and come to a focus at different points along the optical axis. By the proper combination of glasses of different refractive indices, and by grinding the surfaces of the lenses to certain curvatures, opticians have been able to re-combine a few of these rays, and to bring them to one focus to form a sharp image, but it is impossible to bring all the rays together again.

As the yellow region of the spectrum will give the brightest image, all telescopic object-glasses are so constructed as to utilize that particular portion. Hence, in making an object-glass, the extreme ends of the spectrum are neglected, and those rays are either scattered, or have their focus at some other point than that occupied by the visual image.

In the photographic lenses that are in every-day use, opticians have been able to make the visual and the chemical foci coincide more or less accurately by averaging the foci of the different parts of the spectrum, so that when the image is sharp on the ground glass, it will give a sharp impression on the sensitive plate.

When, however, a telescopic object-glass is constructed, other requirements enter into consideration. The image must be more perfect than in the photographic lens, as it will have to be greatly magnified. Every ray, therefore, that goes to make up the image must come exactly to the same focal point; any deviation from this and the result would be blurred. On account of the longer focus in the telescopic objective, the visual and the chemical foci are hopelessly separated.

This yellow region, from which the visual image is formed, is devoid of actinic energy (hence the yellow light for dark rooms). If the image in the telescope is sharply focussed on a ground glass, it will not give a sharp picture, for the visual image will have no effect on the plate; there will be a blurred impression, however, from the actinic image, which will be out of focus at that point. Hence telescopes that are used for celestial photography must be specially corrected for the actinic rays, and are worthless for visual purposes. The great 36-inch refractor of the Lick Observatory has a "correcting lens" which, when placed over the visual

objective, converts it into a photographic lens by bringing the chemical rays to a sharp focus. When this correcting lens is on, the telescope cannot be used visually.

A good many people have, perhaps, tried to photograph with a non-photographic telescope, and have been disappointed with the result because the image was blurred. It is possible, nevertheless, to get extremely satisfactory pictures with any good refracting telescope, but as the visual and chemical foci do not coincide, it is necessary to find the position of the latter with reference to the visual focus. The actinic image is totally invisible on the ground glass, and we have to grope for it in the dark as it were. Its position can easily be found by experiment. Perhaps the following is the best method with a large and properly mounted telescope. A suitable attachment is made to carry the ground glass and plate holder; this takes the place of the eye-piece, and is supposed to be adjusted for changing the focus. If the telescope is directed to a star and allowed to remain stationary, the star will pass across the field of view by the rotation of the earth. Focus the image carefully on the ground glass. It should appear as a tiny point of light. Record this position of the tube. Substitute now the sensitive plate, and adjust the instrument so that the star shall cross the field; give an exposure of, say, half a minute, the telescope remaining stationary. Draw the tube out now about 0.05 of an inch and repeat the exposure. Continue this a number of times, taking care after each exposure to shift the telescope in altitude so that successive trials shall not fall on each other. When the plate is developed it will contain a series of lines or trails produced by the light of the star as it crossed the plate. Some of these will be blurred, but it will be seen that they successively become sharper until one is found that is perfectly sharp (if the experiment has been carried far enough). This will have been made at the chemical focus. The record for this trail compared with the reading when the image was in focus on the ground glass will be the correction to the visual to obtain the chemical focus. Hence, when a photograph is to be made, the image is sharply focussed on the ground glass, the telescope is then adjusted to the chemical focus, and the resulting picture should be sharp. I have said to move the plate away from

the object glass in the search for the actinic focus, because in my experience with four different telescopes, the chemical focus was outside the visual in each case. This focus, may, however, prove to be inside or towards the objective. To identify the first or last trail on the plate, it is only necessary to cover the objective for several seconds during the first or last exposure, and then, by breaking the trail, identify it with certainty.

I have thus experimented with four telescopes and found that in each case they gave very satisfactory photographs at the chemical focus. These were the 6-inch Cooke equatorial, of the Vanderbilt University, Nashville, Tenn., (the chemical focus of this instrument is 0.17 inches outside the visual); a 3¼-inch Clark objective (0.10 inches outside); a 6½-inch Clark equatorial (0.12 inches outside); a 12-inch Clark equatorial (0.24 inches outside). The last three are of the Lick Observatory.

When the amount of light is not of special importance, as in the case of the sun (at an eclipse) or the moon, the image is very much improved by reducing the aperture. Thus with a 3¼-inch Clark objective, reduced to 1¾ inches, photographs were obtained of the corona of the total eclipse of the sun of January 1, 1889, that were comparable in quality with those made at the same eclipse with a 13-inch, specially corrected, photographic telescope. And with the 6½-inch telescope, cut down to 3 inches, Mr. Burnham secured admirable photographs of the corona at Cayenne, South America, during the total eclipse of Dec. 22, 1889. With the same instrument (6½-inch) and an hour and a half's exposure (full aperture) perfectly satisfactory pictures of thirteenth magnitude stars were obtained. These stars were just visible to the eye in the same instrument. Very satisfactory photographs of the moon have been made with the 12-inch, though none of these telescopes are corrected for the chemical rays, and are called non-photographic.

In these experiments a small, flat brass box to carry the plate holder, and fitted to screw onto the telescope in place of the eye-piece holder, was used. This had a narrow slit through which a cardboard slide, with an exposing aperture, could be shoved across in front of the plate in making the exposure.

For the brighter naked-eye stars, an instantaneous exposure is necessary. For the moon, one or two seconds when half full, and 0.2 or 0.3 of a second when full. For making direct enlargements in the telescope, an ordinary negative or positive eye-piece can be employed, but the tube carrying the plate-holder must be very much longer. The correction from the visual to the chemical focus will be the same whether an enlarging lens is used or not. When other than instantaneous exposures are required, it is necessary that the telescope be made to follow the object accurately throughout the exposure.—*From Anthony's International Annual of Photography, 1891.*

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## THE HISTORY OF THE TELESCOPE.*

PROFESSOR C. S. HASTINGS, YALE UNIVERSITY.

There is no instrument which has done so much to widen the scope of human knowledge, to extend our notions of the universe, and to stimulate intellectual activity, as has the telescope, unless the microscope be regarded as a successful rival. But even admitting a parity in scientific importance, the former instrument is incomparably more interesting in its history, in the same degree that its history is more simple and more comprehensible. To trace its development from a curious toy in the hands of its discoverer, for we shall see that this term is more appropriate than inventor, to the middle of this century, is to be brought into contact with most of the great philosophers from the time of the renaissance, who have achieved greatness in physical science, Galileo, Torricelli, Huyghens, Cassini, Newton, Halley, Kepler, Euler, Calaiault, the Herschels, father and son, Fraunhofer, Gauss—from only a portion of the list of great names. Its growth towards perfection has constantly carried with it increased precision in the applied sciences of navigation and of all branches of engineering. It would be easy to show that even pure mathematics would be in a far less forward state had there been no problems of astronomy and physics

* Address delivered at the dedication of the Goodsell Observatory of Carleton College, Northfield, Minn., June 11, 1891.

which were first suggested by the employment of the telescope. It is to this history that I venture to invite your attention this evening. I purpose to review succinctly the origin and development of this potent aid in the study of nature, to name some of the more important achievements depending upon it, and to trace its gradual improvement to the magnificent and complicated instrument which constitutes the modern equatorial. After this sketch I shall try to give an idea of the imperfections which the conscientious artisan has to contend with in attaining perfection, and to make clear the methods which have been employed in reducing these imperfections in the noble instrument now erected at this institution,* and explain why its possessors are so hopeful of gratifying success.

Galileo learned in 1609, while visiting Venice, that a marvelous instrument had been invented the preceding year in Holland, which would enable an observer to see a distant object with the same distinctness as if it were only at a small fraction of its real distance. It required but little time for the greatest physicist of his age to master the problem thus suggested to his mind, and after his return to Padua, where he held the position of professor of mathematics in the famous university of that city, he set himself earnestly to work making telescopes. Such was his success that in August of the same year he sent to the Venetian Senate a more perfect instrument than they had been able to procure from Holland; and in January of the next year, by means of a telescope magnifying thirty times, he discovered the four satellites of Jupiter. This brilliant discovery was followed by that of the mountains in the moon; of the variable phases of Venus, which established the Copernican theory of the solar system as incontestible; and of the true nature of the Milky Way, together with many others of less philosophical importance. Though Galileo did not change the character of the telescope as it was known to its discoverer in Holland, he made it much more perfect, and, above all, made the first and most fertile application of the instrument to increase the bounds of human knowledge, so that it is inevitable that his name should be indissolubly connected with the instrument. Thus the form which he used is to this day known as the Galilean telescope.

* Carleton College.

Considering the enormous interest excited throughout intellectual Europe by the invention of the telescope, it seems surprising that its early history is so confused. Less than two years after it was first heard of, a discovery, perhaps the greatest of a thousand years in the domain of natural philosophy, had been made by its means. Notwithstanding these facts, the three contemporary, or nearly contemporary, investigators assign the honor to three different persons, and if we should write out the names of all those to whom more modern writers have attributed the invention the list would be a long one. The surprise will not be boundless, however, if we consider the task before a historian in the next century who undertakes to justly apportion the honor of the invention of the telephone among its numerous claimants. The analogy, though suggested in the obvious fact that the telephone is to hearing just what the telescope is to sight, may be made much closer if we could imagine the future historian deprived of all but verbal description, that contemporary diagrams and models were wholly wanting. Under such conditions it is difficult to believe that the historian would easily escape antedating the discovery of the telephone proper on account of descriptions, generally imperfect, of the acoustic telephone. But this would fairly represent the condition of the material at the command of an investigator of the present day into a question of science of the early part of the seventeenth century. No wonder, then, that the invention has been attributed to Archimedes, to Roger Bacon, to Porta, and to many others who have written on optics; but to find the name of Satan in the list is certainly surprising. Still we read that a very learned man of the 17th century, named Arias Montanus, finds in the fourth chapter of Matthew, eighth verse, evidence that Satan possessed, and probably invented a telescope; otherwise, how could he have 'shown Him all the kingdoms of the world and the glory of them'?* It seems to be well established now, however, that Franz Lippershey, or Lippersheim, a spectacle maker at Middleburg, was the real inventor of the telescope, and that Galileo's first telescope, avowedly suggested by news of the Hollander's achievement, was an independent invention.

* The history of the telescope is admirably treated in Poggendorff's Geschichte der Physik, from which the statements above are taken.

That this discovery was really an accident we may be quite sure, for not only was there no developed theory of optics at that time, but even the law of refraction, which lies at the basis of such theory, was quite unknown. So, too, it seems to me quite certain that Galileo's invention must have been empirical and guided by somewhat precise information, such as that the instrument consisted essentially of two lenses of which one was a magnifying, and the other a diminishing lens. At least, that Galileo's telescope was like that of the Hollander; that, theoretically considered, it is not so simple as that made of two magnifying lenses, as is evinced by the fact that Kepler, the first philosopher to establish an approximate theory of optical instruments, only two years later, invented the latterand prevailing form; and, finally, that Galileo published no contributions to the theory of optics, seem quite sufficient reasons for such a belief. But, in any case, Galileo's merit is in no wise lessened by having failed to do what could not be done at that time, and the value of his discoveries in emancipating men's minds from authority in matters of pure reason is incalculable.

No other discoveries of great moment were made until over a generation after Galileo proved the existence of spots on the sun in 1611. This cessation of activity was doubtless owing to the difficulty of securing telescopes of greater efficiency than that possessed by Galileo, and which he would hardly have left until its powers of discovery had been fully exhausted in his own hands. By the middle of the 17th century, however, several makers of lenses had so far improved the methods of grinding and polishing, that telescopes notably superior in power to that of Galileo were procurable. Of these Torricelli, Divini, and Campani, all Italians; Auzout, who constructed a telescope 600 feet in length, though no means was ever found for directing such an enormous instrument towards the heavens; but above all, Huyghens, have won distinction as telescope makers. The last named philosopher discovered by means of a telescope of his own construction, the largest satellite of Saturn in 1655, thus adding a fifth member to the list of planetary bodies unknown to the ancients. But his most important astronomical discovery, made also in 1655, was the nature

of the rings of Saturn. This object had greatly puzzled Galileo, to whose small telescope the planet appeared to consist of a larger sphere flanked on either side by a smaller one; but when in the course of the orbital motion of Saturn the rings entirely disappeared he was wholly unable to suggest an explanation. This planet had thus presented a remarkable problem to all astronomical observers for more than forty years, and the records of the efforts to solve it during that interval afford us a most excellent means of judging the progress in practical optics. Huyghens announced these discoveries early in 1656, but that relating to the ring was given in the form of an anagram, the solution of which was first published in 1659. This discovery was contested in Italy by Divini but was finally confirmed by members of the Florentine Academy with one of Divini's own telescopes.

A few years later the famous astronomer Cassini, having come to Paris from Italy as Royal Astronomer, commenced a series of brilliant discoveries with telescopes made by Campani of Rome. With these, varying in length from 35 feet to 136 feet, he discovered four satellites to Saturn in addition to the one discovered by Huyghens. The whole number was increased by Herschel's discovery of two smaller ones in 1789, a hundred and five years after Cassini's last discovery, and again by Bond's discovery of an eighth in 1848. The Saturnian system, to which the telescope has doubtless been directed more frequently than to anything else, thus serves as a record of the successive improvements of the telescope. Highly significant is the fact that the discoveries of the 18th century were made with a reflecting telescope, the others all being with refracting instruments.

Cassini's discovery in 1684 of the two satellites now known as Tethys and Dione, was not accepted as conclusive until long afterwards, when Pound in 1718 with a telescope 123 feet in length, which Huyghens had made and presented to the Royal Society, saw all five. This particular instrument is of especial interest because it is the only one of those of the last half of the 17th century which has been carefully compared with modern instruments. Moreover, it is without doubt quite equal in merit to any of that period. But we find that, although it had a diameter of six inches, its performance was hardly better than that of a perfect mod-

ern telescope of four inches in diameter and, perhaps, four and a half feet in length, while in regard to convenience in use the modern compact instrument is incomparably superior.

Another notable discovery of this period was that of the duplicity of the rings of Saturn by the Ball brothers in 1665, though its independent discovery by Cassini ten years later first attracted the attention of astronomers. The earlier discovery was made by means of a telescope 38 feet long which seems to have been of English manufacture. We must regard Cassini's discovery of the third and fourth satellites of Saturn, however, as marking the very farthest reach of the old form of telescope; a century was to elapse and an entirely new form of telescope was to be developed before another considerable addition to our knowledge of the aspect of the heavenly bodies was to be made. It is true larger telescopes were made, and Huyghens invented a means by which they could be used without tubes, but notwithstanding this improvement they proved so cumbersome as to be impracticable.

The older opticians had found that if they attempted to increase the diameter of a telescope they were obliged to increase its length in a much more rapid ratio to secure distinct vision. The reason of this was not clearly understood, but it was supposed to be owing to the fact that a wave front, changed in curvature by passing through a spherical surface, is no longer strictly spherical. This deviation in shape of the refracted wave from a true sphere is called spherical aberration. When the refracting surfaces are large and of considerable curvature this soon becomes very serious, but by using small curvature, which, in a telescope, obviously corresponds to great length, the effects of the error can be made insensible. Newton's discovery of the composite nature of light and of the phenomenon of dispersion enabled him to explain the true cause of indistinctness in short telescopes; namely, that the refraction by the objective varies for different colors; consequently, if the ocular is placed for one particular color, it will not be in the right position for any of the others, whence the image of a star or planet will seem to be surrounded by a fringe of colored light. Newton found this source of indistinctness in the

image, which is now known as chromatic aberration, many hundred times as serious as the spherical aberration. As he was persuaded by his experiments that this obstacle to further improvement in the refracting telescope was insuperable, he turned his attention to a form of telescope which had been suggested a number of years earlier in which the image was to be formed by reflection from a concave mirror, and constructed a small one with his own hands which is still in the possession of the Royal Society. This little instrument seems to have been of about the same power as Galileo's instrument with which he discovered the satellites of Jupiter, but it was hardly more than six inches in length.

Since that time the reflecting telescope has had a remarkable history of development in the hands of a number of most skilful mechanicians, who have also for the most part been distinguished by their discoveries in physical astronomy; we may, therefore, advantageously depart from the chronological treatment and follow the history of this type of instrument. This course is the more natural because we may probably regard the supremacy of the reflector, undisputed a century ago, as passed away forever.

Even after Newton's invention was made public little was done towards the improvement of telescopes for half a century, until Hadley presented a reflector of his own construction to the Royal Society in 1723 which was found to be equal to the Huyghens refractor of 123 feet in length. From this time we may date the beginning of the superiority of reflectors. A few years later Short commenced his career as a practical optician, and for thirty years he was unapproached in the excellence of his instruments. During this time many telescopes, more powerful than the best of the previous century and infinitely more convenient in use, had been made and scattered throughout Europe, but during this period also there was a singular dearth of telescopic discovery. Perhaps men thought that the harvest had already been gathered; or, perhaps we may find the explanation in that the great cost of telescopes so restricted their use that the impulse to discovery by their means was confined to a very small class. In view of the remarkable manner in which the stand-still in this branch of science was finally followed by a brilliant period of discovery, rivalled alone by that of Galileo, we might well regard the latter cause as the chief one.

William Herschel was born in 1738 in Hanover. In 1755 he left his native country, and, going to England, secured a position as organist in Octagon Chapel, Bath, where we find him in 1766. Here he became so profoundly interested in the views of the heavens which a borrowed telescope of moderate power yielded, that he tried to purchase one in London. The cost of a satisfactory instrument proving beyond his command, he determined to construct one with his own hands. Thus he entered upon a course which was to reflect honor upon himself, his country, and his age, and which was to add more to physical astronomy than any other one man has added before or since. With almost inconceivable industry and perseverance he cast, ground, and polished more than four hundred mirrors for telescopes, varying in diameter from six to forty-eight inches. This in itself would imply a busy life in any artisan, but when we remember that all this was merely subsidiary to his main work of astronomical discovery, we cannot withhold our admiration.

Fortunately for science as well as for himself, he made early in his career a discovery of the very first importance which attracted the attention of all Christendom. On the night of March 13, 1781, Herschel was examining small stars in the constellation of Gemini with one of his telescopes of a little more than six inches in diameter, when he perceived one that appeared "visibly larger than the rest." This proved to be a new world, now known as Uranus. The discovery led in the following year to his appointment as astronomer to the king, George III, with a salary sufficient to enable him to devote his whole time to astronomy.

One of the fruits of this increased leisure was the construction of a telescope far more powerful than had been dreamed of by his predecessors, namely, a telescope four feet in diameter and forty feet in length. Commenced in 1785, Herschel dated its completion as Aug. 28, 1789, when he discovered by its means a sixth satellite of Saturn and, less than a month later, a seventh, even closer to the planet and smaller than the sixth. We may regard this achievement as marking the limit of progress in the reflecting telescope, for although at least one as large is now in use, and one even half

as large again has been constructed, it is more than doubtful whether they were ever as perfect as Herschel's at its best.

There has been one improvement, however, in the reflecting telescope since the time of Herschel which ought not to be left unnoticed here, namely, that of replacing the heavy metal mirror by one of glass, made even more highly reflective than the old mirrors by a thin coating of silver deposited by chemical methods upon the polished glass. The great advantage of this modern form of reflector lies, not so much in the greater lightness and rigidity of the material as in that the surface when tarnished can be renewed by the simple process of replacing the old silver film by a new one; whereas, in the metal reflectors, a tarnished surface required a repetition of the most difficult and critical portion of the whole process of construction. The construction is also so comparatively simple that an efficient reflector is far less expensive than are refracting telescopes of like power, so that this may be regarded as particularly the amateur's telescope. On the other hand, such telescopes are, like their predecessors, extremely inconstant, and they require much more careful attention to keep them in working order. It is for these reasons, doubtless that silver-on-glass reflectors have done so little for the advancement of astronomical discovery. In astronomical photography, however, they promise to do much, and indeed at the present date by far the best photographs we have of any nebulæ have been made by Mr. Common's magnificent reflector of three feet in diameter, and by the twenty inch reflector of Mr. Roberts.

We must go back now to a quarter of century before Herschel discovered the new planet—to the very year, indeed when that great astronomer first set foot on English soil—in order to trace the history of another form of telescope which has remained unrivaled for the last half centnry in the more difficult fields of astronomical research, and which to-day finds its most perfect development in the instruments at Mt. Hamilton, at Pulkowa, at Vienna and at Washington.

Newton had declared that, as a result from his experiments, separation of white light into its constituent colors was an inevitable accompaniment of deviation by refraction, and consequently the shortening of the unwieldy refractors was impracticable. The correctness of the experi-

ments remained unquestioned for nearly a century, but a famous German mathematician, Euler, did question his conclusion. His argument was, that since the eye does produce colorless images of white objects, it might be possible by the proper selection of curves to so combine lenses of glass and of water as to produce a telescope free from the color defect. Although Euler's premise was an error, since the eye is not free from dispersion, his efforts had the effect of leading to much more critical study of the phenomena involved. In this John Dolland, an English optician, met with brilliant success. Repeating an experiment of Newton's with a prism of water opposed by a prism of glass, he found that deviation of light could be produced without accompanying dispersion into prismatic colors. More than this, he found that the two varieties of glass, then as now common in England,—crown, or common window glass, and flint glass, which is characterized by the presence of a greater or less quantity of lead oxide,—possessed very different powers in respect to dispersion. Thus, of two prisms of these two varieties of glass which would deflect the light by the same angle, that made of flint glass would form a spectrum nearly twice as long as the other. Hence, if a prism of crown glass deflecting a transmitted beam of light say ten degrees, were combined with one of flint glass which would deflect the beam of light five degrees in the opposite direction, there would remain a deflection of five degrees without division into color. It also follows that a positive lens of crown combined with a negative lens of flint of half the power would yield a colorless image. Such combinations of two different substances are called achromatic systems.

It is a singular fact, worth noting in passing, that more than twenty years before Dolland's success, Mr. Chester More Hall had invented and made achromatic telescopes, but this remained unknown to the world of science until after Dolland's telescopes became famous.

For a long time this ingenious invention remained fruitless for astronomical discovery, though they were early applied to meridian instruments, on account of the impossibility of securing sufficiently large and perfect pieces of glass, more particularly of flint glass. Not until after the beginning of this century was any real advance in this branch of the arts

exhibited. Even then success appeared, not in England or France where most strenuous efforts had been made to improve the quality of optical glass, but in Switzerland. There a humble mechanic, a watch-maker named Guinaud, spent many years in efforts, long unfruitful, to make large pieces of optical glass. What degree of success he attained there during twenty years of experiment, we do not know, though from the fact that during that peroid good achromatic telescopes of more than five inches in diameter were unknown, we must conclude that his success was limited. In 1805 he joined the optical establishment of Fraunhofer and Utzschneiden in Munich. Here he remained nine years and with the increased means at his disposal and the aid of Fraunhofer, he perfected his methods so far that the production of large disks of homogeneous glass became only a matter of time and cost; that is to say, all of the large pieces of optical glass which have since been produced, whether in Germany, France, or England, have been made by direct heirs of the practical secrets of this Swiss watchmaker.

Fraunhofer was a genius of a high order. Although he died at the early age of thirty-nine, he had not only brought the achromatic telescope to a degree of optical perfection which made it a rival of the most powerful of the reflector type, and so far improved its method of mounting that his system has replaced all others, but he also made some capital discoveries in the domain of physical optics. His great achievement was the construction of an archromatic telescope, nine and six-tenth inches in diameter, with which the elder Struve made at Dorpat his remarkable series of discoveries and measurement of double stars. The character of Struve's work demonstrates the excellence of the telescope and shows us that it is to be ranked as the equal of all but the very best of its predecessors. Indeed, it may fairly be concluded that not more than one or two telescopes, and those made and used by Herschel, had ever been of greater power, while in convenience for use the new refractor was vastly superior.

For a long time Fraunhofer and his successors, Merz and Mahler, from whom the great telescopes of Pulkowa and of the Harvard Observatory were procured, remained unri-

valed in this field of optics. But they have been followed by a number of skilful constructors whose products have, since the middle of the century, been scattered all over the world. In Germany, Steinheil and Schröder; in France, Canchois, Martin and the Henry brothers; in England, Cook and Grubb; and in this country the Clarks and Brashear, each has produced one or more great telescopes which has rendered his name familiar to all readers of astronomical history. Of these the Clarks, father and son, have beyond a doubt won the first place, whether determined by the character of the discoveries made by means of their instruments or by the fact that the two most powerful telescopes in existence were made by them, namely, the new refractor of thirty inches in diameter at Pulkowa and the great refractor of three feet diameter of the Lick Observatory in California. The most notable discoveries made with their telescopes are the satellites of Mars and the companion to Sirius; but besides these there is a long list of double stars of the most difficult character discovered by the makers themselves, by Dawes, in England; by Burnham, in our own country, and by a number of other observers.

We ought not to terminate our review of the development of the telescope without a reference to the parallel development of the mounting of great telescopes. Indeed, did this not lead us too far from the immediate aim in view, we might find a great deal of interest and be brought into agreeable contact with some of the cleverest mechanicians and engineers of two centuries, by tracing its course. We should meet with Huyghens, as the inventor of the aerial telescope, and perhaps consider the claims of his contemporary Robert Hook, as a rival inventor, for we may be sure that nothing which brings us to a study of that curious and able philosopher would fail to possess interest. We should find Herschel confronted with the problem as to how he should use his great forty-foot telescope, and the study of his solution would guide us in valuing the results of the subsequent efforts of Lassel and Rosse. The same line of study would bring us to Grubb's clever and interesting equatorial mounting of that anachronism, the four foot Melbourne reflector. But we should find nothing of very notable interest in the mounting of refractors, after the time of Huyghens

and Hook, until Fraunhofer invented a type of mounting for the famous Dorpat equatorial which still remains in its essential features as the type in universal use. With the increase in size of the telescopes to be directed towards the heavens, however, the number and complexity of the mechanical problems to be solved has been vastly increased, so that they have taxed the best powers of some of the ablest mechanicians. The Repsolds of Germany and Sir Howard Grubb of Dublin have specially distinguished themselves in this field of activity. But it seems to me that none have shown greater fertility of resources, greater skill in the solution of every problem affecting the comfort and efficacy of the observer, and greater taste combined with accurate workmanship, than have the celebrated firm which has mounted the telescope at Mt. Hamilton and that at Carleton College.

We come now to a consideration of the present state of the art of lens making. We ask why such a very large proportion of the telescopes in existence are bad; why there was a time, brief it is true, during which the glass maker was certainly in advance of the demands of telescope makers; and why, finally, the first of the great modern objectives was in the hands of the most skilful optician in Great Britain for seven years, and even then this maker asserted that it was incomplete.

These questions cannot be answered in a word, but we can, at least, gain much in perspicuity by recognizing that the reasons are of two distinct kinds, namely, purely technical and theoretical, and by regarding them briefly in succession.

The art of lens making can be certainly traced back to the 13th century though the methods at a much later day than that were so rude that, as we have seen, Galileo had the utmost difficulty in making a lens good enough to bear a magnifying power of thirty times. At the present day there is little difficulty in selecting a spectacle glass which would rival that most famous of all telescopes. Not until after another generation of effort was there such notable improvement in the technique of lens making that further astronomical discovery was possible. The reasons for this slow progress are to be found in the extremely critical re-

quirements for a good lens. A departure by a fraction of a hundred-thousandth part of an inch from a correct geometrical surface will greatly impair the performance of an objective. But even at this day the limit of accurate measurement may be set at about a one-hundred-thousandth of an inch, while it is quite probable that ten times that value was vanishingly small to the artisans of a century or more ago. It was necessary, therefore, to devise a method of polishing—for it is a comparatively simple matter to grind a surface accurately—which should keep the surface true within a limit far transcending the range of measurements. Huyghens is the first who seems to have done this, by polishing upon a paste which was formed to the glass and then dried, and by using only the central portion of a large lens. In Italy Campani developed a system which he most jealously guarded as a secret until his death, consisting of polishing with a dry powder on paper cemented to the grinding tools. This method still survives in Paris to the exclusion of almost all others, and it is probably the best for work which does not demand the highest scientific precision.

Newton, however, was the first to introduce a method which has since been developed to a state of surprising delicacy. Casting about for a means which should be sufficiently "tender", to use his own expression, for polishing the soft speculum metal, he fixed upon pitch, shaped to the mirror while warm as a bed to hold the polishing powder. But the enormous value of this substance lies not so much in the comparative immunity which it gives from scratching, but in the fact that under slowly changing forces it is a liquid, but under those of short duration it behaves like a hard and brittle solid. Thus it is possible to slowly alter the shape of a lens while polishing, in any desired direction. It was only after the practical recognition of this fact that really excellent lenses were much more than a question of good fortune. The perfecting of this method belongs without doubt to the English of the last century and the early part of this. In the Philosopical Transactions we find many long papers relating to this art, contributed by skilful and successful amateurs. We may, therefore, regard the technique of the art of lens making as practically complete at the middle of this century and as

common property, so that success no longer depends upon the holding of some special or secret method.

We are now, after this, I fear, somewhat dry discussion of a necessary point, in a condition to explain the differences between the processes pursued by most telescope makers and that of the maker of the Carleton College telescope.

This is the ordinary method: After securing perfect pieces of glass, crown and flint, as like as possible to those generally used, and having fixed upon the general shape of the lenses, a guess is made as to the proper radii of the four surfaces to determine the desired focal length and corrections both for color and spherical aberration. The success of this guess has much to do with the necessary outlay of labor, and therefore past experience is of great value as a guide. After working the four surfaces to the dimensions provisionally adopted so far as to admit of fairly good seeing through the objective, an examination of the errors is made. Should the errors of color be so small that their final correction will not make the telescope more than from three to ten per cent. greater or less than the desired focal length, the crown lens will probably be completed in accordance with the provisional figures. Then the flint lens will be modified in such a direction as will tend to correct the observed errors of color and figure, until, by a purely tentative process, the color error is practically negligible and the error of figure is small. Then follows a process when the qualities of skill, conscientiousness and perserveance have full scope. This process first introduced, or at least made public by Foucault, is known as local correcting. It consists in slowly polishing away portions of the lens surfaces so that errors in the focal image become so small, not that they cannot be detected, but that one cannot determine whether they are on the one side of truth or the other. Local correcting has always seemed to me to be eminently unscientific and unnecessary. It is a process of making small, errors which ought not to exist.

Mr. Brashear's method is essentially different from this. Before the glasses are touched every dimension and constant of the finished objective is known with great accuracy. His whole aim is to make the surfaces geometrically perfect; and by ingnious polishing machinery which embodies twelve

years of his thought and experience, he is enabled to do this with truly astonishing exactness. All the surfaces which admit of investigation—usually three in his ordinary construction—are made rigidly true without regard to the character of the focal image. This leaves only one surface which is known to be very nearly a sphere but probably deviating slightly within in the direction of a prolate or oblate spheroid. A glance at the character of the focal image will determine this point. Then the polishing machine is adapted to bring about a change in the proper direction and, after action during a measured interval of time, the image is again examined and from the observed change in character the necessary time for complete correction by the same or contrary action may be deduced. It will be observed that by this means it is quite possible to correct errors which are much too small to betray their nature, since a step in the wrong direction carries with it no consequences of the slightest moment, since any step may be retraced.

When we learn that Mr. Brashear's telescope objectives have always had a focal length differing only from one-tenth to one one-hundred and eightieth of one per cent. of the value prescribed, we have a suggestion of the success of his efforts. But adding to that the fact that he is absolutely untrammelled by purely mechanical considerations, either as to the shape of his lenses or the character of his materials, leaving these questions to be decided alone by the requirements of the astronomer, it seems to me that we may fairly accord to him the merit of the most important improvements introduced into his art for a very long period.

I shall not venture to demand much of your time in considering the purely theoretical difficulties in telescope construction, not merely because the subject has already taxed our patience, but because it would be of almost too technical a character did we allow ourselves to regard anything but the most general features.

The obvious requirements are that in a good objective the light coming from a point in the object should be concentrated at a point in the image; but this, combined with a prescribed focal length, may be reduced to three conditions: first, a fixed focal length; second, freedom from color error;

third, freedom from spherical aberration for a particular color or wave-length of light. Now let us catalogue what provisions we have for satisfying these conditions. They are, four surfaces, which must be spherical but may have any radii we please, the two thicknesses of the two lenses, and the distance which separates the lenses; that is, *seven* elements which may be varied to suit our requirements. As a matter of fact, however, on account of the cost of the material and the fact that glass is perfectly transparent, for powerful telescopes we must make the lenses as thin as possible; and we shall find also that separating the lenses introduces errors away from the axis which are, to say the least, undesirable. We have left, therefore, only the four radii as arbitrary constants. These however are more than enough to meet the three requirements. To make the problem determinate we must add another condition. The suggestion of this fourth condition and carrying the problem to its solution is the work of the great mathematicians who have directed their thought to it. Clairault proposed to make the fourth condition that the two adjacent surfaces should fit together and the lenses be cemented. This condition would be doubtless of great value were it possible to cement large lenses without changing their shapes to a degree which would quite spoil their performance. Sir John Herschel published a very important paper in 1821 in which he made the fourth condition that the spherical aberration should vanish for objects at a very great distance but also for those at a moderate distance. In this paper he computed a table, afterwards greatly extended by Professor Baden Powell, for the avowed purpose of aiding the practical optician. It was this feature undoubtedly which brought his construction, not at all a good one as we shall see, into more general use than any other for some time. But, as all Herschel's tables were derived from calculations which wholly disregard the thickness of the lenses, I am quite unable to see how they could have been of any material aid, and am inclined to suspect that the discredit with which opticians have received the dicta of mathematicians concerning their instruments may have been due in part to this very fact. It is a singular fact for which I have in vain sought the explanation that Fraunhofer's objectives are of

just such a form as to comply with the Herschelian solution although they must have been made quite independently.

Gauss made the fourth condition that another color or wave-length of light should be also free from spherical aberration. This seems to have been a *tour de force* as a mathematician, not as a sober suggestion of an improvement in construction, for in point of fact the construction is very bad. It was generally believed that this condition could not be fulfilled, therefore Gauss, who was particularly fond of doing what all the rest of the world believed impossible, straightway did it. There has been only one effort to carry out this suggestion of Gauss, and that forty years later by Steinheil, but it proved a disappointment. A much larger objective made by Clark a few years ago of the general form of Gauss's objective probably does not meet the Gaussian condition—at least this condition is extremely critical and I believe it is not asserted that the objective was ever thoroughly investigated. It has been the father of no others.

It is hardly surprising, since none of these forms have any real merit, that the practical optician has, following the line of least resistance, adopted a form which costs him less labor than those heretofore mentioned and is quite as good. By making the curve equi-convex the trouble and expense of making one pair of tools is saved, although this would hardly appear a satisfactory reason for choice of a particular form to the astronomer, who simply demands the best possible instrument of research.

The reason for so much futile work on the theory of the telescope objective is not far to seek. It had always been tacitly assumed that the condition of color correction, one of those which serves to determine the values of the arbitrary constants, was readily determinable—in fact, one of the *donne* of the problem, whereas, it is just this datum which has offered peculiar difficulties. Fraunhofer brought all the resources at the command of a genius to bear upon this point, and frankly failed although in the effort he made a splendid discovery which has assured a permanence to his fame no less than that of the history of science itself—the discovery of the dark or Fraunhofer lines, in solar and stellar spectra. Gauss proposed the condition that the best objective is that which produces the most perfect concentra-

tion of light about the place of the geometrical image of a point, just as the best rifle practice is that which produces the maximum concentration of hits about the center of the target. That this is a false guide appears at once from the consideration that if we take even as much as ten per cent. of the light from an object and diverted from the image so far that it cannot be found the telescope may still be practically perfect; all of Herschel's did much worse than this. But if you take that same ten per cent. and concentrate it very close about the image, the telescope will be absolutely worthless.

The true difficulty with most of the theorists is this: There is no recognition of the *relative weight* or importance of unavoidable errors. The optician is confronted at the very outset by the fact that absolute elimination of color error is impossible for certain physical reasons which we have not time for considering farther. He can reduce the color error of the old single lens type of telescopes hundreds of times, and hence the length of the telescope tens of times. It is this fact which prevents the still farther shortening of telescopes, which keeps the ratio of length to diameter not less than fifteen to one in large telescopes. This restriction being recognized let us revise our limiting conditions. They now become, first, fixed focal length; second, best color correction; third, freedom from spherical aberration for a particular wave-length of light. We therefore, have still one arbitrary constant undetermined. How shall we fix its value and thus solve the problem completely? Surely there is only one rational guide. Consider the residual errors and make the fourth condition such as to reduce these errors as far as possible. Now the only remaining errors are secondary color error, and spherical aberration for colors other than that for which it is eliminated, or, more scientifically, chromatic difference of spherical aberration. Which of these is the gravest defect? Our answer must depend upon the use to which the objective is to be put. If it is a high power microscope objective it is certainly the second. If it is an objective to be used for photographing at considerable angular distances from the axis, our question loses its physical significance since we have excluded the consideration of excentric refraction. But if the objective is to be for a visual

telescope there is no question that the defect of secondary color error is indefinitely the most serious. Our fourth and determining condition must, therefore, be *better* color correction.

These are, therefore, the considerations which have served as guides in the construction of the Carleton College objective. First, the selection of the materials which, in the present condition of the art of optical glass making, possess in the highest degree the desired physical properties. Second, a general discussion of every *possible* combination of these two pieces of glass and a selection of the forms which yield the best attainable results. This conscientious strife after scientific perfection, the unexcelled skill with which the results of analysis have been interpreted into the reality of substance, the gratifying identity of predicted and realized values of physical characteristics—all of these have led some of those who have watched the growth of this new instrument of research with the most solicitous attention to the belief that although not the most powerful in existence it may well be the most perfect great telescope yet made. Let us therefore congratulate the possessors of this noble instrument, wish them God speed in their search after knowledge, while we remind them that although no astronomer can ever make another discovery which will rival that made by the insignificant tube first directed towards the heavens by the Paduan philosopher, yet no mind can weigh the importance of any truth, however trivial in appearance, which may be added to that store which we call *science*.

Appendix will appear in Observatory Publication, No. 3.

## THE WILLIAMS TELESCOPE OF GOODSELL OBSERVATORY.

The new Williams equatorial telescope has its name as a memorial to Mrs. Cordelia Bailey Williams late wife of Dr. Edward H. Williams, of Philadephia, who generously provided the money for the purchase of the same, amounting to $15,000.

The clear aperture of the object-glass of the telescope is 16.2 inches, its focal length is 22 feet and its working powers range between 136 and 1,600 diameters. Theory claims that 100 diameters to the inch of diameter of the object-glass is the highest that a telescope will bear. This new instrument, under a power of 1,600, gives good images of stars, in the best 'seeing' and easily separates surprisingly close double stars. Definite results of work in this kind will soon be published that others may judge of its character.

The computations for the curves of the objective were made by Dr. C. S. Hastings, of Yale University, New Haven, Conn., on a new plan, and it is the largest glass that has ever been figured by the new method. His method is radically different from all others now in use. It is based on a careful and exhaustive study of the kinds of optical glass that can be procured anywhere abroad, in order to determine what qualities of glass would fulfill the best conditions for color correction that images seen through the telescope should be true and colorless, as far as possible. After a full discussion of all the available combinations of the different grades of crown and flint glass, involving laborious computations, it was decided to use for the Williams' objective a certain grade of crown glass obtained from Mantois in Paris, and a particular kind of flint glass secured from the works of Schott & Co., Jena, Germany. In this new instrument the per cent. of merit for color correction and blackness of field is claimed by the makers to be much higher than that of any other process of construction now in use. The figures of comparative merit on color correction in the four important modes of object-glass making, *viz.*: that of Gauss, Herschel, equi-convex and Hastings, are respectively 1.00; 1.61; 1.61 and 2.11; figures and names to be taken in the order given. It appears that the Hastings' method is more than 30 per cent. higher in merit than the best previously known. A full statement of the results of the computations by which these figures of merit are reached are already in hand and will soon be published.

The grinding and polishing of the lenses were given to J. A. Brashear, Allegheny City, Pa., to whom there is not a superior in the world, as a maker of perfect surfaces either plane or curved. An instance of his skill is shown in his making four curved surfaces 12 inches in diameter on two discs to work together on a focal length of 18 feet and to come out within five one-hundredths of an inch of the focal length predicted. Dr. Hastings said: "I do not believe there is another man in the world who could have done that." As far as our tests have gone, the Hastings-Brashear glass for the Williams telescope is equally perfect.

The mounting of this instrument was done by Messrs. Warner & Swasey, Cleveland, Ohio, and its general appearance is the same as that of the Lick telescope. The driving clock is also of the same pattern and provided with electrical attachment that acts as a control for any rate of movement desired by the observer. The right ascension clock, electric lamps, glasses and other conveniences for setting the telescope and reading the circles are all that could be desired but the arrangements for slow motions of the telescope are the best we have ever seen.

*Telescope Goodsell Observatory, Carleton College (Apertue 16.2 Inches).*

| | |
|---|---|
| Weight of Tube | 725 lbs. |
| " " " including all parts attached except declination axis | 1300 " |
| Declination Axis | 350 " |
| " " including circles, extension, balance weight, etc. | 700 " |
| Total weight moved in declination 1300 + 700 | 2000 " |
| Weight of polar axis with circles and gears | 725 " |

| | |
|---|---|
| Weight of polar axis with circles and gear, declination sleeve and attachments | 1650 lbs. |
| Total weight moved with polar axis 2000 + 1650 equals | 3650 " |
| Weight of Clock | 160 " |
| Clock Weights | 400 " |
| Weight of column and all stationary parts, etc | 9500 " |
| Total weight of Telescope | 12700 " |

The new universal spectroscope by Mr. Brashear is arranged to be attached to the telescope for study of the physical characteristics of the celestial bodies, or, equally well for use in the physical laboratory. It is provided with electric lamp attachments for comparison spectra and measurements, photographic apparatus, prisms and grating. This fine instrument is adapted to a very wide range of work in the delightful fields of the "New Astronomy" that is claiming so much of the attention of scientists at the present time.

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COMPILED BY WILLIAM C. WINLOCK.

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## CURRENT CELESTIAL PHENOMENA.

### THE PLANETS.

*Mercury* will be at greatest elongation east from the sun, 27° 25′, on Aug. 16, when he will be visible to the naked eye for a short time after sunset. He will be at inferior conjunction with the sun Sept. 12, at midnight, and at greatest elongation west, 17° 53′, Sept. 28.

*Venus* is too nearly in line with the sun to be seen well. Venus and Mars will be in conjunction Aug. 22 at 2 A. M., the apparent distance between the two planets being less than one minute of arc. Venus and Saturn will be in conjunction Sept. 14 at $5^h 32^m$ P. M., Venus being then 32′ south of Saturn. Venus will be at superior conjunction with the sun Sept. 18, at $9^h06^m$ A. M. The planet will then be 1° 17′ north of the sun. This will be a good time to make observations on the crescent of light about the planet, to see if it extends more than 180° around the planet's disk. The observations previously made indicate that the crescent can be seen to extend about three-fourths of the circumference of the disk and on one occasion Professor Lyman was able to distinguish the complete circle. This would indicate that the planet has an atmosphere of considerable density.

*L'Astronomie*, for July, 1891, contains an article on some recent observations of Venus, illustrated by a map of the planet, drawn by M. Niesten, of Brussels, from drawings made by M. Stuyvaert. M. Niesten arrives at a different conclusion from that reached by Schiaparelli and thinks that the period of rotation derived by De Vico, $23^h20^m$, is nearly correct.

*Mars* will not be observable during the remainder of the year.

*Jupiter* is at his best position for this year during August and September. He will be at opposition Sept. 5, rising then at half past six in the evening and setting at half past five in the morning. He is moving slowly westward among the stars of Aquarius and far exceeds them in brightness. That brilliant star which one sees a little south of east in the evening is the planet Jupiter. He is a superb object in the telescope, with his four bright satellites and ruddy colored belts. The great red spot is more conspicuous this year than it has been for several years. It has the same shape of an oval ring, drawn out to a point at each end. The color is a bright pink, decidedly lighter than that of the great southern belt. The central area is white. The spot was on the central meridian of Jupiter a little before midnight, Aug. 3.

*Saturn* is so nearly in line with the sun that satisfactory observations are impossible. This is much to be regretted, since the phenomena attendant upon the disappearance of the rings will be wholly hidden by the solar rays and atmospheric tremors. Saturn will be in conjunction Sept. 13 at 7 A. M. The earth will pass through the plane of the rings Sept. 22, after which, until Oct. 30, the dark side of the rings will be toward the earth.

*Uranus* is getting too near the sun to be observed.

*Neptune* is coming out of the morning twilight, but is not yet in good position for observation.

MERCURY.

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| Sept. 5 | 11 41.2 | − 2 41 | 6 50 A. M. | 12 42.9 P. M. | 6 36 P. M. |
| 15 | 11 10.4 | + 2 27 | 5 20 " | 11 32.8 A. M. | 5 46 " |
| 25 | 11 06.0 | + 6 17 | 4 21 " | 10 49.1 " | 5 17 " |
| Oct. 5 | 11 50.3 | + 3 07 | 4 38 " | 10 54.0 " | 5 10 " |
| 15 | 12 52.0 | − 3 45 | 5 28 " | 11 16.2 " | 5 05 " |

VENUS.

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| Sept. 5 | 10 45.9 | + 9 21 | 5 07 A. M. | 11 47.7 A. M. | 6 28 P. M. |
| 15 | 11 32.1 | + 4 33 | 5 33 " | 11 54.4 " | 6 16 " |
| 25 | 12 17.7 | − 0 29 | 5 59 " | 12 00.0 P. M. | 6 02 " |
| Oct. 5 | 13 03.4 | − 5 32 | 6 25 " | 12 06.9 " | 5 49 " |
| 15 | 13 50.0 | − 10 24 | 6 52 " | 12 14.1 " | 5 36 " |

MARS.

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| Sept. 5 | 10 12.5 | + 12 20 | 4 21 A. M. | 11 14.5 A. M. | 6 08 P. M. |
| 15 | 10 36.6 | + 10 01 | 4 16 " | 10 59.2 " | 5 43 " |
| 25 | 11 00.4 | + 7 37 | 4 10 " | 10 43.6 " | 5 17 " |
| Oct. 5 | 11 23.9 | + 5 08 | 4 04 " | 10 27.7 " | 4 51 " |
| 15 | 11 47.3 | + 2 36 | 3 58 " | 10 11.6 " | 4 25 " |

JUPITER.

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| Sept. 5 | 22 59.6 | − 8 03 | 6 28 P. M. | 11 59.3 P. M. | 5 31 A. M. |
| 15 | 22 54.7 | − 8 33 | 5 46 " | 11 15.2 " | 4 45 " |
| 25 | 22 50.2 | − 9 00 | 5 04 " | 10 31.4 " | 3 59 " |
| Oct. 5 | 22 46.3 | − 9 22 | 4 22 " | 9 48.2 " | 3 14 " |
| 15 | 22 43.5 | − 9 38 | 3 41 " | 9 06.0 " | 2 31 " |

SATURN.

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| Sept. 5 | 11 24.3 | + 5 55 | 5 59 A. M. | 12 26.0 P. M. | 6 53 P. M. |
| 15 | 11 28.9 | + 5 26 | 5 26 " | 11 51.2 A. M. | 6 16 " |
| 25 | 11 33.5 | + 4 57 | 4 54 " | 11 16.5 " | 5 39 " |
| Oct. 5 | 11 38.0 | + 4 29 | 4 21 " | 10 41.8 " | 5 03 " |
| 15 | 11 42.4 | + 4 02 | 3 48 " | 10 06.8 " | 4 26 " |

URANUS.

| Date. 1891 | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| Sept. 5 | 13 48.2 | − 10 37 | 9 28 A. M. | 2 49.5 P. M. | 8 11 P. M. |
| 15 | 13 50.0 | − 10 48 | 8 52 " | 2 12.1 " | 7 32 " |
| 25 | 13 52.2 | − 10 00 | 8 15 " | 1 34.9 " | 6 54 " |
| Oct. 5 | 13 54.4 | − 11 12 | 7 39 " | 12 57.8 " | 6 16 " |
| 15 | 13 56.7 | − 11 25 | 7 03 " | 12 20.8 " | 5 39 " |

NEPTUNE.

| Date. | R. A. | Decl. | Rises. | Transits. | Sets. |
|---|---|---|---|---|---|
| Sept. 5 | 4 30.5 | + 20 15 | 10 00 P. M. | 5 29.3 A. M. | 12 58 P. M. |
| 15 | 4 30.5 | + 20 14 | 9 21 " | 4 50.0 " | 12 19 " |
| 25 | 4 30.3 | + 20 13 | 8 42 " | 4 10.5 " | 11 39 A. M. |
| Oct. 5 | 4 29.8 | + 20 12 | 8 02 " | 3 30.7 " | 10 59 " |
| 15 | 4 29.2 | + 20 10 | 7 22 " | 2 50.8 " | 10 19 " |

THE SUN.

| Date. | R. A. | Decl. | Rises. | Transits. | Sets. |
|---|---|---|---|---|---|
| Sept. 5 | 10 56.8 | + 6 44 | 5 28 A. M. | 11 58.6 A. M. | 6 30 P. M. |
| 15 | 11 32.8 | + 2 57 | 5 39 " | 11 55.1 " | 6 11 " |
| 25 | 12 08.7 | − 0 56 | 5 51 " | 11 51.6 " | 5 52 " |
| Oct. 5 | 12 44.9 | − 4 5[illegible] | 6 03 " | 11 48.4 " | 5 34 " |
| 15 | 13 21.7 | − 8 37 | 6 15 " | 11 45.8 " | 5 16 " |

CERES.

| Date. | R. A. | Decl. | Rises. | Transits. | Sets. |
|---|---|---|---|---|---|
| Sept. 3 | 22 00.0 | − 27 44 | 7 07 P. M. | 11 07 P. M. | 3 07 A. M. |
| 27 | 21 45.1 | − 28 06 | 5 20 " | 9 18 " | 1 16 " |
| Oct. 21 | 21 43.3 | − 26 52 | 3 37 " | 7 42 " | 11 47 P. M. |

PALLAS.

| Date. | R. A. | Decl. | Rises. | Transits. | Sets. |
|---|---|---|---|---|---|
| Sept. 3 | 19 24.0 | + 11 27 | 1 43 P. M. | 8 32 P. M. | 3 21 A. M. |
| 27 | 19 24.6 | + 6 44 | 12 28 " | 6 58 " | 1 28 " |

JUNO.

| Date. | R. A. | Decl. | Rises. | Transits. | Sets. |
|---|---|---|---|---|---|
| Sept. 3 | 21 24.5 | + 6 49 | 4 02 P. M. | 10 32 P. M. | 5 02 A. M. |
| 27 | 21 14.2 | + 10 32 | 2 01 " | 8 47 " | 3 33 " |
| Oct. 21 | 21 19.9 | + 12 51 | 12 24 " | 7 19 " | 2 14 " |

### Configuration of Jupiter's Satellites at 10 p. m., for an Inverting Telescope.

| | | | | | |
|---|---|---|---|---|---|
| Sept. 1 | 2 1 ○ 3 4 | Sept. 16 | 2 ○ 1 3 4 | Oct. 1 | 1 ○ 3 2 4 |
| 2 | 2 ○ 1 4 3 | 17 | 1 3 ○ 2 4 | 2 | 3 ○ 1 2 4 |
| 3 | 3 4 1 ○ 2 | 18 | 3 ○ 1 2 4 | 3 | 3 2 1 ○ 4 |
| 4 | 3 4 ○ 2 ♃ | 19 | 3 2 1 ○ 4 | 4 | 3 2 ○ 1 4 |
| 5 | 4 3 2 ○ ● | 20 | 4 3 2 ○ ♃ | 5 | ● ○ 3 4 2 |
| 6 | 4 1 3 ○ 2 | 21 | 4 ○ 1 3 2 | 6 | 1 4 ○ 2 3 |
| 7 | 4 ○ 1 2 3 | 22 | 4 1 2 ○ 3 | 7 | 4 2 ○ 1 3 |
| 8 | 4 1 2 ○ 3 | 23 | 4 2 ○ 1 3 | 8 | 4 1 ○ 2 3 |
| 9 | 4 2 ○ 1 3 | 24 | 4 1 ○ 2 ♃ | 9 | 4 3 ○ 1 2 |
| 10 | 4 1 3 ○ 2 | 25 | 4 3 ○ 1 2 | 10 | 4 3 1 2 ○ |
| 11 | ● 3 ○ 1 2 | 26 | 3 4 2 1 ○ | 11 | 4 3 2 ○ 1 |
| 12 | 3 2 ○ 4 ● | 27 | 3 4 2 ○ 1 | 12 | 4 1 ○ 3 2 |
| 13 | 3 1 ○ 4 ● | 28 | ○ 1432 | 13 | 4 ○ 1 2 3 |
| 14 | ○ 1234 | 29 | ♃ 1 ○ 4 3 | 14 | 2 4 ○ 1 3 |
| 15 | 1 2 ○ 3 4 | 30 | 2 ○ 1 3 4 | 15 | ● 1 ○ 3 4 |

### Phases and Aspects of the Moon.

| | | Central Time. d | h | m | |
|---|---|---|---|---|---|
| New Moon | Sept. | 3 | 2 | 16 | A. M. |
| Apogee | " | 4 | 2 | 12 | P. M. |
| First Quarter | " | 11 | 5 | 08 | A. M. |
| Full Moon | " | 17 | 11 | 04 | P. M. |
| Perigee | " | 18 | 12 | 24 | A. M. |
| Last Quarter | " | 24 | 5 | 07 | P. M. |
| Apogee | Oct. | 1 | 3 | 48 | " |
| New Moon | " | 2 | 6 | 58 | " |
| First Quarter | " | 10 | 4 | 57 | " |

**Jupiter's Satellites.**

| | | Central Time. h m | | |
|---|---|---|---|---|
| Sept. | 4 | 1 31 | A. M. | I Ec. Dis. |
| | | 3 50 | " | I Oc. Re. |
| | | 10 41 | P. M. | I Sh. In. |
| | | 10 43 | " | I Tr. In. |
| | 5 | 12 46 | A. M. | II Sh. In. |
| | | 12 49 | " | II Tr. In. |
| | | 1 00 | " | I Sh. Eg. |
| | | 1 01 | " | I Tr. Eg. |
| | | 3 39 | " | II Sh. Eg. |
| | | 3 40 | " | II Sh. Eg. |
| | | 7 58 | P. M. | I Oc. Dis. |
| | | 10 16 | " | I Oc. Re. |
| | 6 | 7 11 | " | II Oc. Dis. |
| | | 7 27 | " | I Tr. Eg. |
| | | 7 29 | " | I Sh. Eg. |
| | | 10 03 | " | II Ec. Re. |
| | | 11 51 | " | III Oc. Dis. |
| | 7 | 3 18 | A. M. | III Ec. Re. |
| | 11 | 3 16 | " | I Oc. Dis. |
| | | 6 24 | " | IV Oc. Dis. |
| | | 11 38 | P. M. | IV Ec. Re. |
| | 12 | 12 26 | A. M. | I Tr. In. |
| | | 12 36 | " | I Sh. In. |
| | | 2 44 | " | I Tr. Eg. |
| | | 2 55 | " | I Sh. Eg. |
| | | 3 05 | " | II Tr. In. |
| | | 3 24 | " | II Sh. In. |
| | | 9 42 | P. M. | I Oc. Dis. |
| | | 6 52 | " | I Tr. In. |
| | | 7 05 | " | I Sh. In. |
| | 13 | 1 10 | A. M. | I Ec. Re. |
| | | 9 10 | P. M. | I Tr. Eg. |
| | | 9 24 | " | I Sh. Eg. |
| | | 9 24 | " | II Oc. Dis. |
| | 14 | 12 38 | A. M. | II Ec. Re. |
| | | 3 06 | " | III Oc. Dis. |
| | | 6 38 | P. M. | I Ec. Re. |
| | 15 | 7 04 | " | II Tr. Eg. |
| | | 7 36 | " | II Sh. Eg. |
| | 17 | 6 00 | " | III Sh. In. |
| | | 8 07 | " | III Tr. Eg. |
| | | 9 26 | " | III Sh. Eg. |
| | 19 | 2 10 | A. M. | I Tr. In. |
| | | 2 31 | " | I Sh. In. |
| | | 11 26 | P. M. | I Oc. Dis. |
| | 20 | 2 05 | A. M. | I Ec. Re. |
| | | 3 10 | " | IV Tr. In. |
| | | 8 36 | P. M. | I Tr. In. |
| | | 8 59 | " | I Sh. In. |
| | | 10 54 | " | I Tr. Eg. |
| | | 11 18 | " | I Sh. Eg. |
| | | 11 38 | " | II Oc. Dis. |
| | 21 | 3 14 | A. M. | II Ec. Re. |
| | | 5 53 | P. M. | I Oc. Dis. |
| | | 8 34 | " | I Ec. Re. |
| | 22 | 5 47 | " | I Sh. Eg. |
| | | 6 30 | " | II Tr. In. |
| | | 7 22 | " | II Sh. In. |
| | | 9 21 | " | II Tr. Eg. |
| | | 10 14 | " | II Sh. Eg. |
| | 24 | 8 05 | " | III Tr. In. |
| | | 10 03 | " | III Sh. In. |
| | | 11 27 | " | III Tr. Eg. |
| | 25 | 1 28 | A. M. | III Sh. Eg. |
| | 26 | 3 55 | " | I Tr. In. |
| | 27 | 1 11 | " | I Oc. Dis. |
| | | 4 00 | " | I Ec. Re. |
| | | 10 21 | P. M. | I Tr. In. |
| | | 10 54 | " | I Sh. In. |
| | 28 | 12 39 | A. M. | I Tr. Eg. |
| | | 1 13 | " | I Sh. In. |
| | | 1 54 | " | II Oc. Dis. |
| | | 5 49 | P. M. | IV Ec. Re. |
| | | 7 38 | " | I Oc. Dis. |
| | | 10 29 | " | I Ec. Re. |
| | 29 | 7 05 | " | I Tr. Eg. |
| | | 7 42 | " | I Sh. Eg. |
| | | 8 48 | " | II Tr. In. |
| | | 10 00 | " | II Sh. In. |
| | | 11 40 | " | II Tr. Eg. |
| | 30 | 12 52 | A. M. | II Sh. Eg. |
| Oct. | 1 | 7 07 | P. M. | II Ec. Re. |
| | | 11 25 | " | III Tr. In. |
| | 2 | 2 05 | A. M. | III Sh. In. |
| | | 2 48 | " | III Tr. Eg. |
| | 4 | 2 57 | " | I Oc. Dis. |
| | 5 | 12 06 | " | I Tr. In. |
| | | 12 49 | " | I Sh. In. |
| | | 2 24 | " | I Tr. Eg. |
| | | 3 07 | " | I Sh. Eg. |
| | | 7 21 | P. M. | III Ec. Re. |
| | | 9 24 | " | I Oc. Dis. |
| | 6 | 12 24 | A. M. | I Ec. Re. |
| | | 5 45 | P. M. | IV Tr. In. |
| | | 6 33 | " | I Tr. In. |
| | | 7 18 | " | I Sh. In. |
| | | 8 51 | " | I Tr. Eg. |
| | | 9 36 | " | I Sh. Eg. |
| | | 9 38 | " | IV Tr. Eg. |
| | | 11 08 | " | II Tr. In. |
| | 7 | 12 38 | A. M. | II Sh. In. |
| | | 12 48 | " | IV Sh. In. |
| | | 2 00 | " | II Tr. Eg. |
| | | 3 30 | " | II Sh. Eg. |
| | | 6 53 | P. M. | II Ec. Re. |
| | 8 | 5 19 | " | II Oc. Dis. |
| | | 9 43 | " | II Ec. Re. |
| | | 2 49 | A. M. | III Tr. In. |
| | 12 | 1 53 | " | I Tr. In. |
| | | 2 44 | " | I Sh. In. |
| | | 7 55 | P. M. | III Oc. Re. |
| | | 8 11 | " | III Ec. Dis. |
| | | 11 10 | " | I Oc. Dis. |
| | | 11 23 | " | III Ec. Re. |
| | 13 | 2 20 | A. M. | I Ec. Re. |
| | | 8 19 | P. M. | I Tr. In. |

| Central Time. h m | | | Central Time. h m | |
|---|---|---|---|---|
| | 9 13 P. M. | I Sh. In. | 8 49 P. M. | I Ec. Re. |
| | 10 37 " | I Tr. Eg. | 11 30 " | IV Oc. Dis. |
| | 11 31 " | I Sh. Eg. | 15 3 28 A. M. | IV Oc. Re. |
| 14 | 1 28 A. M. | II Tr. In. | 6 00 P. M. | I Sh. Eg. |
| | 3 17 " | II Sh. In. | 7 39 " | II Oc. Dis. |
| | 5 37 P. M. | I Oc. Dis. | | |

**Minima of Variable Stars of the Algol Type.**

U CEPHEI.

R. A..............$0^h$ $52^m$ $32^s$
Decl.............. + 81° 17′
Period..........2*d* $11^h$ $50^m$

| | |
|---|---|
| Sept. 2 | 10 P. M. |
| 7 | 10 " |
| 12 | 10 " |
| 17 | 9 " |
| 22 | 9 " |
| 27 | 9 " |
| Oct. 2 | 8 " |
| 7 | 8 " |
| 12 | 8 " |

ALGOL.

R. A.............$3^h$ $01^m$ $01^s$
Decl..............+ 40° 32′
Period..........2*d* $20^h$ $49^m$

| | |
|---|---|
| Sept. 12 | 3 A. M. |
| 14 | midn. |
| 17 | 8 P. M. |
| Oct. 2 | 4 A. M. |
| 5 | 1 " |
| 7 | 10 P. M. |

λ TAURI.

R. A..............$3^h$ $54^m$ $35^s$
Decl..............+ 12° 11′
Period.........3*d* $22^h$ $52^m$

| | |
|---|---|
| Oct. 2 | 3 A. M. |
| 6 | 2 " |
| 10 | 1 " |
| 13 | midn. |

U CORONÆ.

R. A............$15^h$ $13^m$ $43^s$
Decl...............+ 32° 03′
Period 3*d* $10^h$ $51^m$

| | |
|---|---|
| Sept. 21 | 11 P. M. |
| 28 | 8 " |

U. OPHIUCHI.

R. A...........$17^h$ $10^m$ $56^s$
Decl...............+ 1° 20′
Period........0*d* $20^h$ $08^m$

| | |
|---|---|
| Sept. 4 | 10 P. M. |
| 10 | 7 " |
| 15 | 8 " |
| 20 | 9 " |

U OPHIUCHI, Cont.

| | |
|---|---|
| Sept. 25 | 9 P. M. |
| 30 | 10 " |
| Oct. 5 | 11 " |
| 11 | 8 " |
| 16 | 9 " |

Y CYGNI.

R. A...........$20^h$ $47^m$ $40^s$
Decl............+ 34° 15′
Period........1*d* $11^h$ $57^m$

| | |
|---|---|
| Sept. 2 | 1 A. M. |
| 5 | 1 " |
| 8 | 1 " |
| 11 | 1 " |
| 14 | 1 " |
| 17 | 1 " |
| 20 | 1 " |
| 23 | 1 " |
| 26 | 1 " |
| 29 | 1 " |
| Oct. 1 | midn. |
| 4 | " |
| 7 | " |
| 10 | " |
| 13 | " |

## COMET NOTES.

Wolf's comet is becoming an easy object for small telescopes. With our 16-inch it has a sharp stellar nucleus of about 12th magnitude, with a considerable condensation about it and a tail about 5′ in length. Prof. Barnard, at Lick Observatory, has picked up Encke's comet in the place predicted by Backlund, whose ephemeris we give below. We have twice looked for the Temple-Swift comet, but have not yet been able to detect it. It was in 1880 a faint, diffuse object several minutes in diameter. It ought soon to be picked up by some one. It will be nearest the earth in November.

*Ephemeris of Comet 1891 (Wolf's Periodic Comet).*

| Gr. M. T. | App. R. A. h m s | App. Decl. ° ′ | log Δ | log *r* | Br. |
|---|---|---|---|---|---|
| Aug. 10 | 2 38 42 | + 28 9.2 | | | |
| 11 | 41 21 | 28 5.2 | 0.0832 | 0.2068 | 5.7 |
| 12 | 43 59 | 28 0.8 | | | |
| 13 | 46 37 | 27 55.0 | | | |
| 14 | 49 14 | 27 50.5 | | | |

| Gr. M. T. | App. R. A. h m s | App. Decl. ° ′ | log Δ | log r | Br. |
|---|---|---|---|---|---|
| 15 | 51 51 | 27 44.7 | 0.0707 | 0.2053 | 6.0 |
| 16 | 54 27 | 27 38.4 | | | |
| 17 | 57 2 | 27 31.6 | | | |
| 18 | 2 59 36 | 27 24.3 | | | |
| 19 | 3 2 10 | 27 16.6 | 0.0581 | 0.2041 | 6.4 |
| 20 | 4 43 | 27 8.4 | | | |
| 21 | 7 14 | 26 59.7 | | | |
| 22 | 9 44 | 26 50.5 | | | |
| 23 | 12 14 | 26 40.9 | 0.0455 | 0.2032 | 6.8 |
| 24 | 14 43 | 26 30.8 | | | |
| 25 | 17 10 | 26 20.1 | | | |
| 26 | 19 36 | 26 9.0 | | | |
| 27 | 22 0 | 25 57.3 | 0.0329 | 0.2026 | 7.3 |
| 28 | 24 23 | 25 45.2 | | | |
| 29 | 26 46 | 25 32.5 | | | |
| 30 | 29 7 | 25 19 3 | | | |
| 31 | 31 26 | 25 5.6 | 0.0204 | 0.2022 | 7.7 |
| Sept. 1 | 33 44 | 24 51.3 | | | |
| 2 | 36 0 | 24 36.6 | | | |
| 3 | 38 15 | 24 21.3 | | | |
| 4 | 40 28 | 24 5.6 | 0.0080 | 0.2022 | 8.2 |
| 5 | 42 39 | 23 49.3 | | | |
| 6 | 44 49 | 23 32.4 | | | |
| 7 | 46 57 | 23 15.0 | | | |
| 8 | 3 49 2 | + 22 57.1 | 0.9957 | 0.2024 | 8.6 |

*Ephemeris of the Temple-Swift Periodic Comet.*

(Continued from page 287.)

| 1891 | App. R. A. h m s | App. Decl. ° ′ | log Δ | Ab. T. m s | $\frac{1}{r^2 \Delta^2}$ |
|---|---|---|---|---|---|
| Sept. 4 | 21 33 02 | − 2 18.2 | 9.6353 | 3 35 | 2.66 |
| 8 | 27 45 | − 1 43.9 | | | |
| 12 | 22 41 | − 1 08.0 | 9.5946 | 3 16 | 3.50 |
| 16 | 17 58 | − 0 30.0 | | | |
| 20 | 13 52 | + 0 10.4 | 9.5587 | 3 0 | 4.49 |
| 24 | 10 25 | + 0 53.6 | | | |
| 28 | 07 55 | + 1 40.0 | 9.5265 | 2 48 | 5.65 |
| Oct. 2 | 06 24 | + 2 30.1 | 9.5114 | 2 42 | 6.30 |
| 4 | 06 04 | + 2 56.8 | | | |
| 6 | 06 02 | + 3 24.8 | 9.4965 | 2 36 | 7.01 |
| 8 | 06 19 | + 3 54.0 | | | |
| 10 | 06 55 | + 4 24.7 | 9.4817 | 2 31 | 7.77 |
| 12 | 07 51 | + 4 56.9 | | | |
| 14 | 09 09 | + 5 30.8 | 9.4667 | 2 26 | 8.61 |

*Ephemeris of Encke's Comet for 1891.*

| | App. R. A. h m s | App. Decl. ° ′ | log Δ | log r | Ab. T. |
|---|---|---|---|---|---|
| | 4 26 10 | + 32 0.0 | 0.1972 | 0.1525 | |
| 11 | 4 30 25 | 32 14.2 | 0.1429 | 0.1476 | 11 39 |
| 12 | 4 24 47 | 32 28.2 | 0.1385 | 0.1416 | |
| 13 | 4 39 17 | 32 42.0 | 0.1340 | 0.1356 | 11 20 |
| 14 | 4 43 55 | 32 55.4 | 0.1294 | 0.1296 | |
| 15 | 4 48 37 | 33 8.6 | 0.1248 | 0.1236 | 11 2 |
| 16 | 4 53 28 | 33 21.4 | 0.1201 | 0.1176 | |

| | App. R. A. h m s | App. Decl. ° ′ | log Δ | log r | Ab. T. |
|---|---|---|---|---|---|
| 17 | 4 58 27 | 33 33.9 | 0.1153 | 0.1115 | 10 44 |
| 18 | 5 3 34 | 33 45.9 | 0.1104 | 0.1054 | |
| 19 | 5 8 50 | 33 57.4 | 0.1054 | 0.0993 | 10 21 |
| 20 | 5 14 14 | 34 8.0 | 0.1003 | 0.0932 | |
| 21 | 5 19 46 | 34 18.8 | 0.0952 | 0.0871 | 10 9 |
| 22 | 5 25 27 | 34 28.5 | 0.0900 | 0.0811 | |
| 23 | 5 31 17 | 34 37.3 | 0.0847 | 0.0751 | 9 52 |
| 24 | 5 37 17 | 34 45.4 | 0.0793 | 0.0691 | |
| 25 | 5 43 27 | 34 52.6 | 0.0737 | 0.0630 | 9 36 |
| 26 | 5 49 47 | 34 58.8 | 0.0680 | 0.0571 | |
| 27 | 5 56 18 | 35 3.8 | 0.0622 | 0.0512 | 9 20 |
| 28 | 6 2 59 | 35 8.0 | 0.0563 | 0.0454 | |
| 29 | 6 9 50 | 35 10.7 | 0.0504 | 0.0396 | 9 6 |
| 30 | 6 16 51 | 35 11.9 | 0.0443 | 0.0339 | |
| 31 | 6 24 1 | 35 11.6 | 0.0380 | 0.0284 | 8 52 |
| Sept. 1 | 6 31 22 | 35 9.5 | 0.0316 | 0.0229 | |
| 2 | 6 38 53 | 35 5.5 | 0.0251 | 0.0176 | 8 39 |
| 3 | 6 46 34 | 34 59.9 | 0.0184 | 0.0124 | |
| 4 | 6 54 25 | 34 52.8 | 0.0115 | 0.0074 | 8 26 |
| 5 | 7 2 24 | 34 43.5 | 0.0045 | 0.0025 | |
| 6 | 7 10 31 | 34 31.8 | 9.9974 | 9.9978 | 8 15 |
| 7 | 7 18 45 | 34 17.6 | 9.9901 | 9.9935 | |
| 8 | 7 27 7 | 34 0.5 | 9.9826 | 9.9891 | 8 5 |
| 9 | 7 35 36 | 33 40.9 | 9.9749 | 9.9850 | |
| 10 | 7 44 11 | 33 18.9 | 9.9671 | 9.9813 | 7 57 |
| 11 | 7 52 32 | 32 54.6 | 9.9590 | 9.9779 | |
| 12 | 8 1 37 | 32 28.0 | 9.9508 | 9.9747 | 7 50 |
| 13 | 8 10 25 | 31 58.4 | 9.9424 | 9.9719 | |
| 14 | 8 19 15 | 31 25.1 | 9.9336 | 9.9693 | 7 44 |
| 15 | 8 28 | 30 49.3 | 9.9246 | 9.9671 | |
| 16 | 8 36 58 | 30 10.9 | 9.9154 | 9.9653 | 7 40 |
| 17 | 8 45 49 | 29 29.7 | 9.9060 | 9.9638 | |
| 18 | 8 54 39 | 28 45.5 | 9.8964 | 9.9629 | 7 37 |
| 19 | 9 3 28 | 27 58.5 | 9.8864 | 9.9623 | |
| 20 | 9 12 15 | 27 9.0 | 9.8761 | 9.9620 | 7 36 |
| 21 | 9 20 59 | 26 16.9 | 9.8655 | 9.9626 | |
| 22 | 9 29 38 | 25 22.5 | 9.8546 | 9.9634 | 7 37 |
| 23 | 9 38 11 | 24 25.8 | 9.8434 | 9.9644 | |
| 24 | 9 46 38 | 23 26.7 | 9.8319 | 9.9656 | 7 40 |
| 25 | 9 55 0 | 22 25.7 | 9.8200 | 9.9677 | |
| 26 | 10 3 16 | 21 22.9 | 9.8078 | 9.9700 | 7 44 |
| 27 | 10 11 26 | 20 18.4 | 9.7953 | 9.9728 | |
| 28 | 10 19 30 | 19 12.2 | 9.7823 | 9.9760 | 7 51 |
| 29 | 10 27 27 | 18 4.7 | 9.7689 | 9.9797 | |
| 30 | 10 35 18 | 16 55.8 | 9.7552 | 9.9838 | 7 59 |
| Oct. 1 | 10 43 3 | 15 45.8 | 9.7410 | 9.9883 | |
| 2 | 10 50 43 | 14 34.7 | 9.7267 | 9.9931 | 8 10 |
| 3 | 10 58 18 | 13 22.6 | 9.7120 | 9.9983 | |
| 4 | 11 5 48 | 12 9.8 | 9.6968 | 0.0039 | 8 22 |
| 5 | 11 13 14 | + 10 56.2 | 9.6814 | 0.0098 | |

*Ephemeris of Comet a 1891. (Barnard Mar. 29.)* From the elements of my orbit as given in THE SIDEREAL MESSENGER for June, p. 288, I have computed the following ephemeris:

| Gr. M. T. | App. R. A. h m s | App. Decl. ° ′ | Log r | Log Δ | Light. |
|---|---|---|---|---|---|
| July 1.5 | 8 35 8 | − 50 29 | 0.1699 | 0.1183 | 0.25 |
| 2.5 | 8 42 53 | 50 25 | | | |

| Gr. M. T. | App. R. A. h m s | App. Decl. ° ′ | Log r | Log Δ | Light. |
|---|---|---|---|---|---|
| July 3.5 | 8 50 23 | −50 20 | | | |
| 4.5 | 8 57 40 | 50 14 | | | |
| 5.5 | 9 4 43 | 50 7 | 0.1893 | 0.1448 | 0.21 |
| 6.5 | 9 11 31 | 49 59 | | | |
| 7.5 | 9 18 7 | 49 51 | | | |
| 8.5 | 9 24 32 | 49 41 | | | |
| 9.5 | 9 30 43 | 49 31 | 0.2076 | 0.0715 | 0.17 |
| 10.5 | 9 36 40 | 49 21 | | | |
| 11.5 | 9 42 26 | 49 10 | | | |
| 12.5 | 9 48 2 | 48 58 | | | |
| 13.5 | 9 53 27 | 48 46 | 0.2248 | 0.1980 | 0.14 |
| 14.5 | 9 58 42 | 48 34 | | | |
| 15.5 | 10 3 46 | 48 22 | | | |
| 16.5 | 10 8 40 | 48 11 | | | |
| 17.5 | 10 13 26 | 47 59 | 0.2413 | 0.2240 | 0.11 |
| 18.5 | 10 18 2 | 47 47 | | | |
| 19.5 | 10 22 29 | 47 35 | | | |
| 20.5 | 10 26 49 | 47 24 | | | |
| 21.5 | 10 31 1 | 47 12 | 0.2569 | 0.2492 | 0.09 |
| 22.5 | 10 35 4 | 47 1 | | | |
| 23.5 | 10 39 1 | 46 50 | | | |
| 24.5 | 10 42 53 | 46 39 | | | |
| 25.5 | 10 46 38 | 46 28 | 0.2719 | 0.2737 | 0.08 |
| 26.5 | 10 50 14 | 46 17 | | | |
| 27.5 | 10 53 46 | 46 6 | | | |
| 28.5 | 10 57 13 | 45 56 | | | |
| 29.5 | 11 0 36 | 45 46 | 0.2861 | 0.2970 | 0.07 |
| 30.5 | 11 3 56 | 45 35 | | | |
| 31.5 | 11 7 13 | − 45 25 | 0.2930 | 0.3085 | 0.06 |

O. C. Wendell

Harvard College Observatory, June 10, 1891.

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## ASTRONOMY FOR AMATEURS.

### How to See the Solar Prominences with a Grating Spectroscope.

E. E. READ, Jr.

For The Messenger.

Recently I have received several inquiries, mostly from amateurs, asking for instruction in the use of the grating spectroscope. They all complain that there is a lack of definite and condensed directions in that line. On account of these inquiries I have written the following paper, which is entirely for the use of amateurs, containing as it does only the most elementary and simple matters in relation to seeing and measuring the solar prominences:

First, Instumental Requisites.

A.—The plane of the slit plate and the plane of the grating must be normal to the line passing through the center of the lens of the equatorial and the lens of the collimator. This line must pass through the center of the slit and center of the grating.

B.—The angle between the collimator and the observing telescope must be as small as possible.

C.—The equatorial must be run with some kind of clock-work. I find that one of the most general inquiries is, "Can I see the solar prominences with a portable equatorial without clock-work?" Upon the whole I should say that a clock-work is an indispensible accessory to good spectroscopic work. The clock need not, however, be an expensive nor elaborate one. Of course an electrically controlled clock connected with the Sidereal clock is the most desirable of all, and to do the most exact work is the only thing, but for the ordinary purposes of amateur work any arrangement by which the equatorial is carried with a regular and steady motion will suffice. Mr. Hopkinson, of Renovo, Pa., has an arrangement that, while costing but a trifle performs quite satisfactorily. He connects a large iron weight by a rope or wire to the axis of the telescope and this he rests on a rubber bag filled with air. A small rubber tube leading from the bag to his hand controls the outlet of the air and the consequent fall of the weight and motion of his telescope. If the telescope is moving too slowly he simply lets more air out and the weight falls faster and the rate of his "clock" is increased. With this arrangement he tells me that he is able to hold a star in the field of view for more than an hour. Then he simply again fills up the rubber bag with air and his "clock" is wound up. With such an arrangement as this an amateur could do very satisfactory prominence work.

### Second, Adjustments.

A.—Detach the observing telescope from the spectroscope and focus it for parallel rays by observing some distant object. This object, if terrestial, should not be less than a mile distant, but if the observer will focus at night upon a star he will then be sure to get parallel rays. Let this focus be marked by means of a scratch or other such mark upon the draw tube.

B.—With the telescope thus focused and again attached to the spectroscope view the image of the slit as it is reflected from the face of the grating. Move the slit plate in or out until the image of the slit is perfectly sharp. Professor Young suggests that a better plan is if practicable to have the spectroscope so constructed that the observing telescope can be swung around far enough to look directly through it into the collimator. Then if the grating is removed the slit can be seen directly and the slit plate moved until the slit is sharp. This plan does away with the reflection entirely. Mark the slip tube of the collimator when this adjustment has been completed as in the case of the observing telescope.

C.—With the instrument thus focussed and collimnated place it so that the slit plate is exactly in the focus of the equatorial. This can be done either by direct observation of the solar image on the slit plate or by viewing the spectrum of the limb of the sun through the telescope. This latter plan is carried out as follows—with the slit radial to the sun the solar image is allowed to fall on it so that only half of the slit is covered, then the observer looking into the observing telescope will see only half the field filled with the spectrum and the line of division will be the spectrum of the sun's limb. If, now, the spectroscope is moved until this line is perfectly sharp the plane of the slit will be in the focal plane of the equatorial for those rays which the observer is using.

If the former method is used it is well to protect the eyes from the glare of the solar image by means of colored glass of some sort. I use a pair o ordinary "London smoke" eye glasses.

4.—Move the equatorial until the solar image is exactly tangential to the slit, and in the C line the chromosphere ought to be seen, together with any prominences that happen to be at the point of observation. The C line of the second order is the line most generally used for this part of the work.

The observer will soon find that one side of his grating will give him better results than the other, the image will be brighter and the light better. It is well to begin operations upon the north and south limbs of the sun because any irregularities of the clock will merely carry the solar image along the slit instead of across it, and in this latter case the light of the photosphere would at once blot out the feeble light of the prominences. The observer will find what width he can open the slit. This depends upon several factors, the most important of which is the atmosphere.

THIRD, CAUSES OF FAILURE.

A.—Air currents of unequal temperature. There is nothing that sooner feels the influence of poor definition than the spectroscope. The heating of the air in the upper part of the Observatory, or even the heating of that in the tube of the equatorial is sufficient to render observations useless. To overcome the former I find that the best time to observe, especially in summer, is the very early morning. My own Observatory is in the heart of a city and unless I make my observations during the summer before eight o'clock, the heat so ruins the definition that seeing is impossible. If the observation is a prolonged one the air in the tube will become so heated that this will affect the seeing. When this happens the only thing to do is to stop work, revolve the roof until the sun no longer falls on the tube of the equatorial and give the air time to cool off.

B.—Moisture in the atmosphere. If the sky is covered with a thin white haze it is useless to attempt to see any prominences. The best sky, however, I find, is not one that is perfectly free from clouds but rather one that is filled with those great masses of snow white cumuli leaving here and there between them patches of sky of an intense blue. These clouds seem to gather up all the moisture that is in the air and leave the clear places perfectly dry and pure. Upon such occasions as these I have obtained the best results.

C.—A dirty object-glass in the equatorial or a dirty grating. The way to clean the latter is to wipe it in the direction of the ruling with a cloth wet with bi-sulphide of carbon.

D.—Lack of sufficient care in the matter of focusing. This is, I find, one of the most usual causes of failure. The observer is too easily satisfied that he has placed the spectroscope so that the focal plane and the slit plate are coincident.

Nor, however, is it always the fault of the observer. If the lens of the equatorial is not well corrected for spherical aberration there is no single point where all the rays come to a focus, and instead of there being a focal plane there is, so to speak, a focal cylinder and all the observer can do is to find the point where he will get the best results. Professor Young's method

for final adjustment in the focal plane is as follows: "I always make the final adjustment of slit in focal plane by help of the eye-piece of the view telescope. I close the slit and focus just as sharply as I can on the Fraunhofer lines. Then I open the slit a little and look at the prominences, running the view telescope eye-piece in and out a little. If the eye-piece shows them best a little inside the focus for the Fraunhofer lines, then I move the spectroscope closer to the telescope, and vice versa if the prominences show best by pulling out the eye-piece beyond the focus of the Fraunhofer lines. The motion of the slit plates should be just half the displacement of the eye-piece between the focus for lines and for prominencs, *i. e.*, it should be so if collimator and view telescope have the same focal length."

FOURTH, MEASUREMENT OF PROMINENCES.

A.—Position Angle. Allow the sun to run along the slit plate and revolve the spectroscope until the north and south limb of the sun is exactly tangential to the slit during the entire passage across the plate. This will then be the zero point, provided, of course, that the north limb of the sun is made use of. Around the eye-end of the tube of the equatorial I have a circle divided to half degrees. Connected with the spectroscope is a pointer that points to the readings on the circle. The pointer is so set that it is directed to 360 when the north limb of the sun is exactly tangential to the slit. Then as the spectroscope is revolved the pointer marks exactly what is the position-angle of the portion of the sun under observation. This reading can be afterwards reduced to latitude, if desired, by means of the solar ephemeris in "The Companion to the Observatory," or the table in Secchi's "Le Soleil."

B.—Measurement of height of Prominences. This can be done either by means of the micrometer or by means of the slit. If the slit is controlled by a screw with a micrometer head the value of the revolution of the screw can be ascertained in about the same method as is used in the ordinary stellar micrometer. The slit can be opened a certain and well ascertained width, say five revolutions of the screw, then the grating having been removed the observing telescope is revolved so that it looks directly through the collimator and equatorial and a star can be allowed to drift across the slit; its time changed to equatorial time and multiplied by fifteen will give the value of the five revolutions of the screw of the slit.

If the cob-web micrometer is used the method is about the same. The spectroscope is arranged as is for the examination of the Fraunhofer lines. The slit is placed parallel to a circle of declination and the wires separated by an integral number of revolutions of the screw. Then as the snn crosses the slit plate let the observer note the interval between contact of the spectrum with the first wire and contact with the second. This interval changed to seconds of arc will be the value of the integral number of revolutions of the screw and the value of a single revolution or fraction thereof can be at once found.

In cases where the prominences are too high to admit of being seen and measured by means of the micrometer and tangential slit other methods must be used. One of the simplest is to place the slit radical to the sun at the point at which the prominence is located and measure its height by means of the micrometer. This method is exact but slow, and if quicker

work is desired recourse can be had to the method of the screen placed behind the finder, or, to refraction of the solar image by means of a plate of thick glass placed at an angle before the slit plate. Both these methods are decribed at length in Secchi, (Le Soleil Vol. II, page 24).

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**School of Pure Mathematics and Practical Astronomy.**

COURSE OF STUDY (PROVISIONAL).

## FIRST YEAR.

**Fall Term, Fifteen Weeks.**

1. Chauvenet's Trigonometry; three hours per week.
2. Analytic Geometry (Howison or Equivalent); two hours per week.
3. [Theory of Equations, Salmon's Higher Plane Curves; Ball's History of Mathematics.]
4. French or German, with Translations from Current Periodicals.
5. Practical Astronomy, Observing Exercises from Webb, Oliver and others; Instruments: Opera Glass, Sextant, and Portable Equatorial Telescopes; Principal Themes: Occultations and Variable Stars

**Winter Term, Ten Weeks.**

1. Analytic Geometry (including Three Dimensions), three hours per week.
2. Differential Calculus, two hours per week.
3. French or German with Translations from Current Periodicals.
4. [History of Astronomy; Grant; Determinants].
5. Computations; four hours per week.
6. Practical Astronomy; Principal Theme, Time and the Care of Clocks; Instruments: Portable Transit and the Meridian Circle.

**Spring Term, Eleven Weeks.**

1. Integral Calculus; three hours per week.
2. Analytic Mechanics; two hours per week.
3. [History of Astronomy of the Nineteenth Century; Clerke; Quaternions.]
4. Computations; four hours per week.
5. Astronomy, Chauvenet Vol. I; three hours per week.
6. Observing two nights per week; Theme: Latitude; Instruments: Portable Transit and Zenith Telescope.

## SECOND YEAR.

**Fall Term, Fifteen Weeks.**

1. Astronomy, Chauvenet Vol. 1 completed; two hours per week.
2. Analytic Mechanics; three hours per week.
3. Computation of Orbits, Oppolzer, French or German edition, Klinkerfues and Watson.
4. [Ferris' Spherical Harmonics and Frost's Curve Tracing.]
5. Observing two nights per week. Theme: Double Stars. Instruments: Clark's 8¼-inch Equatorial; Williams 16.2-inch Equatorial; Working Lists from Gledhill, Chambers and Burnham.

**Winter Term, Ten Weeks.**

1. Astronomy, Chauvenet Vol. II begun; three hours per week.
2. Computation of Orbits, Oppolzer, continued.
3. Laboratory work in Physics, Light and Heat, three hours per week.
4. Observing two nights per week. Theme: Differential Observations of Planets; Equatorial Telescope with Micrometer.
5. [Differential Equations; Reference Books: Boole, Johnson and Craig.]

**Spring Term, Eleven Weeks.**

1. Computations of Orbits, Oppolzer, continued.
2. Astronomy, Chauvenet, Vol. II. completed; two hours per week.
3. [Differential Equations, continued.]
4. Observing two nights per week, Meridian Circle.
5. Laboratory Work in Physics, Electricity and Magnetism.

## THIRD YEAR.

**Fall Term, Fifteen Weeks.**

1. Spectrum Analysis, Scheiner, Spectral Analyse der Gestirne; three hours per week.
2. Theme for Original Investigation in some branch of Mathematics or Astronomy.
3. Elliptic Functions.
4. Observing two nights per week, Meridian Circle.
5. [Figure of the Earth, Pendulum Observations; Pratt, Clarke and other books of reference.]

**Winter Term, Ten Weeks.**

1. Spectrum Analysis continued; Laboratory Work with the Universal Spectroscope aided by Photography; three hours per week.
2. Celestial Photography; Themes; Reference Papers in the Library; Instruments: Photographic Telescopes.
3. Theme for Original Investigation in some branch of Mathematics or Astronomy.
4. Observing two nights per week; Equatorial Telescope.
5. [Elliptic Functions, continued.]

**Spring Term, Eleven Weeks.**

1. Theme for Original Investigation in some branch of Mathematics or Astronomy.
2. Celestial Photography continued; Instruments: Photographic Telescopes and Cameras.
3. Calculus of Variations by Topics; Books of Reference: Todhunter, Jellett and other authors.
4. Observing two nights per week; Equatorial Telescope.
5. [Memoirs of Sir Isaac Newton by Brewster, and Dreyer's Tycho Brahe].

NOTE.—The themes in brackets are to be read by the student under the direction of the instructor.

Any student who has received the degree of Bachelor of Arts or Bachelor of Science, and who has completed the above course of study and presented a thesis showing ability in original investigation will be recommended by the Faculty of the College to the Board of Trustees for the degree of Doctor of Philosophy.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, August 1, 1891.

## NEWS AND NOTES.

Vacation months for this year are July and September. Hence the next issue will be for October, and it will be mailed the last week of September.

The size and quality of this number of THE MESSENGER, it is hoped, will be a pleasant surprise to our readers. It is partly due to pressure of useful matter when a vacation month comes.

The attention that has recently been given to studies by the spectroscope has interested a number of the best astronomers in this country and Europe in THE MESSENGER, and arrangements are now in progress for a large, full, and more general discussion of the varions branches of astro-omical work due to the spectroscope, in future numbers of this publication.

*Kenwood Physical Observatory.*—On another page will be found a description of the new Kenwood Physical Observatory, of Chicago. The cuts accompanying the article give a very correct idea, in outline, of this new Observatory, and Professor Young's address, at its dedication, well indicates the auspicious beginning which it has already made. Professor Geo. E. Hale, its director, is now in Europe for study, and at this writing is at Mr. Lockyer's Observatoy. He will be abroad at least a year, and in the mean time he is having some new astronomical instruments constructed for his new Observatory in Chicago.

*Professor George Davidson*, of the United States Coast and Geodetic Survey, has just received a letter from his colleague John E. McGrath in charge of the boundary survey party on the Yukon river near its crossing of the 141st meridian, in which McGrath reports that he observed the first interior contact of Mercury and the sun's limb on the 9th of May; and that on the 6th of June he observed the solar eclipse. He took photographs of both these phenomena. Camp Davidson, where McGrach made these observations, is in 65° latitude and 141° longitude.

*Allegheny Observatory.*—At a meeting of the Board of Trustees of the Western University of Pennsylvania, on May 11, 1891, J. E. Keeler, of Lick Observatory, was elected Professor of Astro-physics in the University and Director of the Allegheny Observatory. Mr. F. W. Very is associated with him as Adjunct Professor of Astronomy. It is expected that the Observatory will continue its researches on important problems in the domain of Astro-physics, and he asks that astronomers generally will, as heretofore, favor the Observatory with the communication of such memoirs or shorter papers as may be published under their direction.

*Goodsell Observatory, Carleton College.*—Our readers will notice that the Observatory has received a new name since our last publication. It was given in comemoration of Mr. C. F. Goodsell, the real founder of Carleton College. A full account of the earnest work and self-denying service of this good man, to found a Christian College in the Northwest, will be given in Observatory Publication No. 3, which will appear soon. This name was given in connection with the reception exercises for the new large equatorial and the formal opening of the School of Pure Mathematics and Practical Artronomy, as part of the proposed work of the Goodsell Observatory. The dedication and reception exercises were held on and about the east porches of Gridley Hall, Carleton College, June 11, 1891. A special free train from the cities of St. Paul and Minneapolis was provided for the occasion, and nearly 100 invited guests from the cities spent the day and evening in witnessing the various exercises of Commencement Day and the interesting views of celestial objects at the Observatory during the evening by the aid of the large telescope. The occasion was one of great interest to the College and to the Observatory. The persons who shared in the special exercises before referred to, were President Strong, the Director of the Observatory, Professor Goodhue, Profesor Huntington, Professor J. L. Noyes and Mr. M. W. Skinner, all of Carleton College; Professor C. S. Hastings of Yale University, Mr. Warner of Cleveland, Ohio, Rev. E. H. Avery of Iowa, Hon. M. H. Dunnell of Owatonna, Mr. H. S. Fairchild of St. Paul, Rev. S. S. B. Spear of Minneapolis. As indicated above, a very full account of these special exercises will be given in the next Observatory Publication.

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*Professor L. G. Weld* of the State University of Iowa spent a few days with us at the Observatory trying the instruments and looking up points of interest.

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*Professor W. A. Crusenbury*, Department of Mathematics and Astronomy, Callinan College of Drake University, Des Moines, Ia., is spending a part of his vacation at the Goodsell Observatory in regular work with the astronomical instruments.

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*Camberlin Observatory.*—Under date of June 19, Professor H. A. Howe, Director of the Chamberlin Observatory, Denver, Colo., writes that "the plasterers begin to-morrow their work in the new observatory building." that the dome is almost done, the objective is completed and that the mounting for the 20-inch glass is likely to be completed during the present summer. At last writing Professor Howe was testing his new 6-inch equatorial telescope.

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*Students' Observatory, at Berkley, Cal.*—Roger Sprague, who is spending his vacation at the Students' Observatory, of Berkley, California, describes at length the defining power of the fine six-inch telescope at that place. He calls attention to the "granular appearance" of the principal condensation as being peculiar, and suggests that this part of the nebula possibly might be watched with profit. This granular appearance has before been noticed, but later study is quite decisive in the view that the con densed portions of the nebula are not [illegible] able.

*The Proper Motion of* $\Sigma$ *1321.* The expression Mr. Burnham uses in the SIDEREAL MESSENGER p. 171, "only optically double," is likely to be misleading, as not used, as it appears to me, in the usual sense given by astronomers to it. He uses it in the cases of stars which, like 61 Cygni and $\Sigma$ 1321, though physically connected, have not been proved to have any motion around each other, and therefore are not called "binary;" but my impression is that astronomers generally use the expression to mean stars which are nowhere near each other in space, but only happen accidentally to lie nearly in the same line of sight.

As an illustration, I believe it would generally be said that five of the bright stars in Ursa Major, $\beta$, $\gamma$, $\delta$, $\epsilon$, $\zeta$ are "physically connected," and are not "only an optical group;" but that $\alpha$ and $\eta$ are probably not physically but "only optically" connected with the others.

T. W. BACKHOUSE.

West Hendon House, Sunderland, England, July 14, 1891.

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*Another Iowa Meteorite.*—What is supposed to be a meteoric stone fell five miles north and four and a-half miles east of Alta, Iowa, about 3:15 A. M. of the 2d of June. The person who found the stone thus described the circumstances of its fall to me: "A bright flash of red light was first seen, followed by a buzzing sound and a very loud report which was said to be much louder than thunder, immediately something appeared to hit the side of the house (possibly gravel). The occupants (two women) at first thought the house had been struck by lightning, and, being frightened, did not venture out until morning, when, looking around, they found, embeded a few inches in the sand and gravel quite near the house, the aerolite. It was covered with a black substance, had a strong smoky and sulphurous odor. They washed it and brought it to town. I examined it and found it of a concavo-convex shape, nearly round, being about four inches by three and three-fourths inches and two inches high in the center, weighing one pound and fifteen ounces avoirdupois. The concave side is partly stone and metal and the convex side is completely covered with a small crystalline, yellowish-green metal, partly fused by heat on one side. It looks as if it might have been globular and been shattered in two.

DAVID E. HADDEN.

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*Transit of Mercury.* The transit of Mercury was successfully observed at the Observatory of the University of Mississippi on the 9th day of May. An equatorial by Merz of 11.6 cm. aperture (with screen of 8.9 cm. aperture) was used. The eye-piece had a magnifying power of 177. The day was cloudless and conditions all favorable excepting nearness to the horizon, and excessive quivering due to rapid warming of the ground. Time of first contact was lost by imperfect adjustment of wire in eye-piece. Second contact was noted at G. M. T. $11^h\ 57^m\ 31^s$. The first flash of light behind the planet was seen at this time, and it was continuous after this. A "black drop" appearance lasting not more than a second was noted about five seconds before the first flash of light behind the planet. No indications of atmosphere were noted. The planet was watched until sunset. Weather on this occasion, as on the occasion of the transits of Mercury in 1878 and Venus in 1882, was all that could be desired. R. B. FULTON.

University of Mississippi.

*Jupiter.* The great red spot on Jupiter has again become very conspicuous. Its outline is sharply defined and its color a deep pink, similar to its appearance in 1879-80. Another reddish spot has been observed in latitude 9 seconds south of the equator, and following the great red spot about five hours in time. This object has a length at mean distance of 7″.5 and a breadth of 1″. In 1890 *five* small reddish spots were observed in the north margin of the equatorial belt, 5″ north of the equator, the approximate rotation period being $9^h$ $55^m$ $34^s$. One of these spots was observed on July 9, preceding the great red spot $2^h$ $07^m$ of time. I presume others will become visible during the opposition. The oval white spots which I have observed every year on belt No. 6, 9″ south of the equator, owing to the more favorable position of the planet, will be more readily seen than for some years past. These spots are usually found in groups of three or more and give a rotation period approximately the same as the great red spot. The most conspicuous spot of a group is now visible, following the great red spot $3^h$ $40^m$ time.

G. W. Hough.

*Photographic Chart of the Sky.* We have just received the report of the last reunion of the International Committee on the photographic chart of the sky. This report is full of interesting matter on the subject of stellar photography, and covers 135 pages. The eighteen observatories are all ready to begin the actual work, having already taken a number of satisfactory trial plates.

The following table gives the list of Observatories, their latitudes, the zone of sky assigned to each and the number of plates required to cover each zone:

| Observatories. | Latitude. | Zone in Decl. | Number of Plates. |
|---|---|---|---|
| Greenwich | + 51°29′ | + 90° to + 65° | 1149 |
| Rome | + 41 54 | + 64 " + 55 | 1040 |
| Catane | + 37 30 | + 54 " + 47 | 1008 |
| Helsingfors | + 60 09 | + 46 " + 40 | 1008 |
| Potsdam | + 52 23 | + 39 " + 32 | 1232 |
| Oxford | + 51 46 | + 31 " + 25 | 1180 |
| Paris | + 48 50 | + 24 " + 18 | 1260 |
| Bordeaux | + 44 50 | + 17 " + 11 | 1260 |
| Toulouse | + 43 37 | + 10 " + 5 | 1080 |
| Alger | + 36 48 | + 4 " − 2 | 1260 |
| San Fernando | + 36 28 | − 3 " − 9 | 1260 |
| Tacubaya | + 19 24 | − 10 " − 16 | 1260 |
| Santiago | − 33 27 | − 17 " − 23 | 1260 |
| La Plata | − 34 35 | − 24 " − 31 | 1360 |
| Rio-de-Janeiro | − 22 54 | − 32 " − 40 | 1376 |
| Cape of Good Hope | − 33 56 | − 41 " − 51 | 1512 |
| Sydney | − 33 52 | − 52 " − 64 | 1400 |
| Melbourne | − 37 50 | − 65 " − 90 | 1149 |

H. C. W.

*Lightning Spectra.* We have been greatly interested in the study of lightning spectra, as carried on by Mr. W. E. Wood, of Washington, D. C. Below we give a portion of a recent private letter from him on this subject. Although not written for publication we are sure it will interest students in spectroscopy, and probably lead some of the more experienced workers to aid him by answering his pertinent queries:—

In the August (1890) number of THE MESSENGER, place was given to some "preliminary" observations on "Lightning Spectra," made by the Browning spectroscope. Since that time, I have pursued the subject, and with the assistance of a well supplied laboratory belonging to Mr. W. K. Carr of this city, and which has an imposing array of electrical appliances, Geisler tubes, etc., I have considerably advanced my knowledge of electric spectra of all kinds, and which I find exceedingly interesting. But to be brief—I must modify somewhat the earlier observations, which, it will be remembered, were preliminary only. I am now prepared to say, that lightning spectra present but the characteristic lines of oxygen, hydrogen, nitrogen, and carbonic acid, and—what was puzzling to me—the line of the vapor of sodium. The absorption bands, which I find in lightning spectra, I think might be produced by the moisture in the air, a large quantity being present during thunder storms. I can account for the sodium line in several ways, namely:

1st. Dust, containing earthly vegetable matter, held in suspension in the atmosphere.

2d. Vapor carried by winds from the ocean, into the vortex of the storm and containing salty material.

3d. The presence of sodium as an element of the atmosphere.

I favor this point because I can get the sodium line not only by means of an electric flash in any state (with the exception possibly of the spark in vacuo which I have not yet obtained,) in the atmosphere, but I have noticed that in purest states of the air, when, I considered the presence of dust of any kind to be almost beyond detection, that a Bunsen burner will give the D line many times during a period of one minute. Of course the line given was extremely faint, but certainly present.

4th. It might be finally ascertained that the sodium line was a feature of the electric spark in all of its various apparitions. This is not improbable, for, if the two poles of a weak battery be brought in contact with the tongue, while no shock might result, a pecular taste is left, proving some chemical action. Since the spark of an electric machine gives the sodium line equally with the spark from a chemical solution battery, it would be unwise to say that the sodium line originated from the chemicals composeing the battery solution. The greatest obstacle appears to be, the production of a spark free from metallic influences originating from the electrodes; for no matter how we produce the spark it will be subject to the influences of whatever electrode we use. At present I can think of nothing suitable to use for the purpose. Perhaps some one might suggest-something out of which to form the electrodes, and which would positively give off no sodium vapor. If so, I shall be pleased to continue the investigation, for I am anxious to find whether or not the origin of the D line visibility lies in the electric spark.

5th. The last I shall offer, and to me the most reasonable of all, is this: It is an accepted fact that there is precipitated on the earth's surface, daily, great quantities of meteoric matter, popularly called "star dust." Such spectroscopic examinations as have been made of some of this meteoric matter by Lockyer and others, have shown,—if I remember correctly—that sodium vapor is always present. Now, much of this stel-

lar dust is on account of its extreme fineness, held in suspension in the atmosphere; and those particles which obstruct the passage of the electric spark, in the case of lightning are readily vaporized, and the familiar sodium line attests the presence of these particles. Accepting the theory that the atmosphere is at all times laden with meteoric particles in a state more or less densely situated, we need not wait for lightning to prove it, but we can with an ordinary Bunsen burner, at well chosen times of serenity of the atmosphere, attest the evidence of lightning spectra. In order to more fully investigate this point, I shall continue a series of observations with the Bunsen burner, and, if possible, with the electric spark, in this manner: I shall arrange an apparatus at the top-most platform of the dome of the capitol building, and shall choose an early morning hour—say from two to four o'clock—at such time as the atmosphere shall have been in a quiescent state for some hours One can readily see, that by such an arrangement I shall attain the most perfect results. The dust raised from the earth by vehicles and winds during the day will, with a few hours, atmospheric rest, to a great extent—if not wholly—subside, and come to rest at the earth's surface. Now if this meteoric dust be continually precipitated, it is obvious that it will be always present, and falling,—the supply coming from above. I am confident that if this sodium line fail or become extremely weak at such times, that I must look for its origin elsewhere: and if I get it at all times, even when exposed plates of glass fail to catch, by their prepared surfaces particles of matter of earthly origin, (and easily analyzed as such by a series of such plates prepared at different times.) I can, determine closely the origin of that sodium, and further consideration will show you that I can pretty closely determine with the gas flame and spark whether or not the sodium line belongs to electricity.

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*That Wondnrful Niagara Meteor.* Often in popular works on astronomy, and far too frequently in astronomical text-books, we find stated as a fact that during the great star-shower of Nov. 13, 1833, a meteor hung over Niagra Falls for half an hour and emitted radiant streams of ligl t. A greater absurdity than this never tound its way into publication. The originator of the tale probably thought that celestial visitants, as well as mundane inhabitants, ought to feel the entrancement of the wonderful beauty of the cataract, and that, therefore, this one determined to halt and devote a half an hour to its inspection. But though the sensational writer was thus particular in relating the time of its lingering over the Falls, he unfortunately omitted to tell us how near it approached them and whither it betook itself. It is difficult to treat with seriousness a story so at variance with our knowledge of the behavior of meteoroids when they enter the atmosphere. Those only which emanate exactly from the radiant appear to stand still, and these are visible for only about a single second, instead of a half-hour, and during that brief interval they are estimated to move with a speed equal to the sum of the velocities of both the earth and the meteor, which rate of motion must be so enormusly increased by the earth's attraction as to cause it to approach the earth from 75 to 100 miles per second.

It chanced that I was an observer of the unexampled meteoric display of 1833, at a point sufficiently near the Falls to have witnessed such a

sight had it existed, but nothing of the kind was seen by any one of a group of a half dozen of people who observed it with me. Evidently this story should be relegated to that large class of astronomical myths which too many times pass current as facts.

A large meteor may have exploded over the locality, and the *debris* have been seen for the time named, a phenomenon occasionally witnessed as I myself saw at the return of the shower in 1867. LEWIS SWIFT.

Warner Obs'y, Rochester, N. Y., July 16, 1891.

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*Solar Disturbances and Terrestrial Magnetism.* In THE SIDEREAL MESSENGER for November, 1889, I called attention to a periodicity of the aurora at intervals of "twenty-six or twenty-seven days." By the aid of longer lists of auroras and an improved method of tabulation this period has been amended by successive approximations until twenty-seven days, six hours and forty minutes has been secured as the final result, which corresponds precisely to the most generally accepted value for a synodic revolution of the sun as determined from the average rate of movement of sun-spots. Tables showing the numbers of stations reporting auroras each day in all accessible lists have been constructed at this interval for nearly two hundred years and the periodicity described is evident more or less throughout. Cumulative evidence has been secured also to the effect that it is when disturbed areas are at or near the eastern limb appearing by rotation that they have the power of producing magnetic phenomena chiefly if not exclusively. Certainly the recurring outbursts of auroras are of such brief durations as to demonstrate clearly that the originating solar disturbances have this power during a very limited portion only of each transit. Some months since Professor C. A. Young wrote to me stating in substance that in view of these results it becomes necessary to admit that the sun has more coherence than has been supposed, and that it may even contain a solid nucleus. He stated further that a few years since he would have said that it makes no difference whether a solar disturbance is on the earth-ward side of the sun or not so far as magnetic effect is concerned, but that now it becomes necessary to admit that this power of solar disturbances is related to their visibility. He also, asked whether I had any objection to his refering to this point in an article which he was writing at the time. Presented in this way, and with this qualification, I had no objection to offer. Unfortuuately I have not seen Professor Young's article. but I presume that a note in THE SIDEREAL MESSENGER for May, at page 250, refers to it, stating as it does, that "Professor Young has recently called attention to the rediscovery in the United States that there is a connection between visibility from the earth of solar disturbances and terrestrial magnetism." As it seems to me a statement so indefinite as this in regard to the nature of the connection referred to is liable to have various meanings read into it and to be misconstrued. It is evident from what has been said above that the magnetic effect of solar disturbance is not dependent simply upon their visibility, otherwise this effect would continue as long as they are in sight on the earth-ward side of the sun, which is most decidedly not the case. In deed there is positive proof in the tables referred to that we must look elsewhere than to light radiations for the means of conveyance of magnetic im-

pulses from sun to earth. It would be premature perhaps to enter upon the detailed discussion of this proof which is in process of investigation rather than at the stage at which the announcement of conclusions is warranted. It will be found ere long, I think, that the subject is a very live one and I should be well pleased to have the benefit of any contributions which Mr. Sherman, whom you mention in the note above quoted, or any one else, may be prepared to make to it.

May 4, 1891.

Since sending the letter of May 4th I have seen the article of Professor Young's mentioned in it. I find that he is of the opinion that my results in regard to a periodicity of the aurora corresponding to the time of a revolution of the sun, as viewed from the earth, are consistent with certain discoveries of Herz in regard to magneto-electric properties of light. After very careful study of the various pecularities of this periodicity I am very decidedly of the opinion that the solar impulses originating terrestrial magnetic phenomena are *not* conveyed either as light or heat in any form whatever. My reasons will become apparent soon, I hope, when a portion, at least, of the tables upon which they are based shall have been published, together with the necessary comments and explanations. I am very much pre-occupied and the necessary clerical work of arranging the data, etc., is slow. I trust, however, to have the results in such shape that they may be verified by anyone who cares to look into the matter ere long. I am becoming more aud more convinced that these results are destined to have a very important bearing upon meteorology. M. A. VEEDER.

May 15, 1891.

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*Observatory of the University of Mississippi.* It may interest the readers of your very valuable "MESSENGER" to know that the University of Mississippi has arranged with the establisment of Sir Howard Grubb for the construction of an instrument that will be capable of doing good work. It is to be of the "twin equatorial" type after the style of the instrument planned by Janssen at Meudon, and will consist of a 15-inch visual telescope and a 9-inch photographic telescope, side by side, on the same support and controlled by the same mechanism. The instrument will be provided with every useful device that Grubb has used successfully with his larger instruments. Work upon it has been progressing satisfactorily for two months, and it is expected to be in place about May 1st, 1892. It will occupy the pier built for the 18½-inch equatorial now at Dearborn Observatory, which was constructed by Alvan Clarke & Sons for the University of Mississippi under the direction of Dr. F. A. P. Barnard. Upon its completion in 1862, Dr. Barnard very properly advised the makers to dispose of it as they thought best, as nothing had been paid them, and the war rendered its final acceptance by the University of Mississippi doubtful. While we will not have now what we would have had in 1862,—the leading telescope in America,—it is expected that the purchase of the new instrument will mark the beginning again of astronomical work that has been interrupted many years by war and consequent financial inability. We need further equipment, but men of wealth, and liberal men of wealth, are not numerous in this section, so we are by degrees working up to the expectations of thirty years ago. R. B. FULTON.

University Mississippi, July 6, 1891.

*Small Telescopes Bought and Sold.* We have had so much correspondence about small telescopes during the last year that we have decided to devote one or more of our advertising pages to information of this kind, especially in regard to second-hand telescopes, in the interest of those who wish to buy or to sell such instruments. Naturally enough persons who wish to buy such telescopes are timid lest they be cheated in the operation. We cannot recommend a telescope that we have not seen and so we have been unable, in many instances, to help persons in this way who really need aid.

Now, we make this suggestion: That any person having a good, second-hand telescope who wishes to sell it, may try to do so through our agency, for new and second-hand instruments. The telescope should be sent to "Goodsell Observatory of Carleton College, Northfield, Minn.," transportation prepaid, and we will give it a careful examination and publish an account of its condition and the owner's terms of sale.

In case of sale we will charge ten per cent. for all values under $500. For values over $500 special arrangements will be made. If an instrument is not sold within four months it will be returned at owner's expense and no charge will be made for examination and advertising. If the owner still wishes to keep his instrument in the agency for sale, special arrangements to that effect may be made. Correspondence is therefore solicited from all persons wishing either to sell or to buy second-hand astronomical instruments.

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*Professor Geo. E. Hale* has recently been elected Professor of Physics at Beloit College, Wis., and also lecturer on the same subject at the Northwestern University. Professor Hale's present plan is to furnish a course of lectures on physics for the coming year at Beloit College, and to give a shorter course to Professor Hough's students in the Northwestern University.

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*School of Pure Mathematics and Practical Astronomy.*—In this number will be found a provisonal Course of Study for another department of work undertaken at the Goodsell Observatory of Carleton College. One class of two members has already been pursuing this course during the last year. Another class will form at the opening of College in September next. We do not know of an Observatory in this country where a student can pursue a course of post-graduate study in Mathematics and Astronomy more favorably or more systematically than at Goodsell Observatory. Correspondence is solicited with persons who are Bachelors of Arts or Bachelors of Science from Colleges of good standing, wishing further study in these branches.

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## BOOK NOTICES.

Lessons in Astronomy Including Uranography. A brief introductory course without mathematics, for use in schools and seminaries. By Charles A. Young, Ph. D., LL. D. Publishers, Messrs. Ginn & Company, 1891. pp. 357.

This new book was written to meet the want of certain classes of schools which find the author's "Elements of Astronomy" rather too hard

for their courses and pupils. From a full examination of the book, it is evident that the whole matter has been carefully worked over, simplified and re-written, to adapt it to wants of that grade of pupils for which it is intended. In this work we feel sure Professor Young has done better for these pupils than he himself believes, judging from the semi-apology he makes for the book in the preface.

It is so easy for the experienced scholars, writers and teachers in higher branches to forget the many difficulties that the student meets in his first attempts at elementary work, that they are in danger of requiring constantly too much of the beginner. They expect such to know too much, or to acquire new things too easily. Now we have had the impression that our distinguished author has been just a little at fault in this direction, and that his standard in all three of his books on Astronomy is a little severe for the grade of scholarship for which they are respectively written. This, we know, is a good fault, and one greatly to be preferred to weakness of subject-matter in a text-book. A tendency, even, to such an extreme rightly would disgust a good teacher, and a change of book would soon be the remedy.

The first chapter is devoted to fundamental notions and definitions, and then follows a very useful chapter on Uranagraphy, in which is given a brief description of sixty-six constellations, with four double page maps, showing how they are related and all the stars properly designated, down to, and including, the fifth magnitude. At the close of this chapter is a table containing the names of the constellations, the right ascension and declination of each and the number of stars in each, also. Any student with this little book in hand, may locate most of these constellations and a larger part of the 1688 stars to be found in them on these maps. That chapter alone is worth many times the book to any one who wants to make a naked eye study of the heavens.

The other features of the book are those common to a good elementary text, except that the latest information from all lines of active study in the various branches of astronomy, is found in its proper place. It seems to us that teachers of almost any grade of class in Astronomy will find this book a very useful one for reference.

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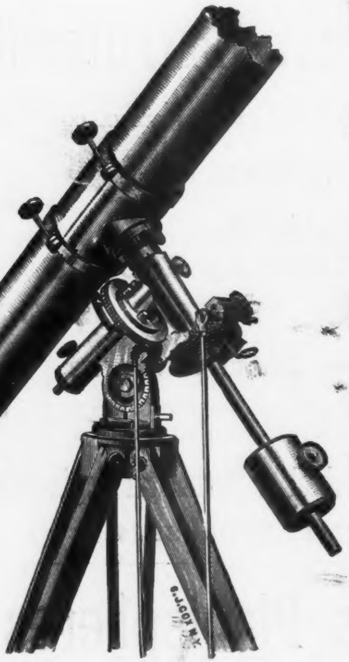
A Higher Algebra, by G. A. Wentworth, Professor of Mathematics in Philip Exeter Academy, Boston, Mass., half morocco, 528 pages. Mailing price $1.55, for introduction, $1.40.

This new book is designed to prepare for colleges and scientific schools, and to furnish in addition what is needed for the *general student* in such institutions. It is equivalent to the author's Complete Algebra, and goes farther in some things, and in some other respects is better. It is, of course, more complete than the School Algebra. It provides in a single book a course parallel to both the School and College Algebra. It is an Algebra that teachers will do well to examine, for its author is one of the most popular writers in the line of school and college text-books in mathematics that our country can boast of.



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